

**DECONSTRUCTING PUBLIC PERCEPTIONS OF NOVEL FOOD TECHNOLOGIES:  
HUMAN VALUES AND INFORMATION COMMUNICATION STRATEGIES**

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Saskatoon

By

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## ABSTRACT

Based on insights of behavioural economics, this thesis aims to provide a more nuanced understanding on determinants of consumers' acceptance of novel food technologies. In particular, this thesis explores how consumers' attitudes and food choices related to innovative food technologies are affected by '*inside*' individual factors, such as underlying human values (i.e., cultural worldviews and food-related values), and '*outside*' environmental factors, such as the information framing (i.e., narrative communication). Each paper focuses on one particular factor that motivates disparate assessments of food technologies.

Empirical data on consumers' food technology attitudes and food choice behaviours were collected from a nation-wide Internet survey administered to 1608 Canadian consumers in 2016. Half of the respondents participated in the Biotechnology version survey, and the other half of respondents completed the Nanotechnology version survey. Both versions of online survey incorporated a choice experiment, where respondents selected their most preferred sliced apple products from a set of hypothetical alternatives. Each paper focuses on particular research questions thus uses different sections of this extensive survey.

Paper 1 explores information framing effects by comparing the effectiveness of using logical-scientific vs. narrative information to communicate about food biotechnology to consumers. A logical-scientific information condition about biotechnology was developed and written in a scientific style using the passive voice with generalized and impersonal language. In contrast, a narrative-style information condition about the technology was written in a more lively and vivid personal style. Respondents were randomly assigned to different information treatments. Results indicate that information about food biotechnology shown in different formats (logical-scientific vs. narrative) or being accessed by respondents in different manners (forced exposure or voluntary choice) can have differing impacts on perceptions and preferences. Compared with logical-scientific information, narratives and/or voluntary information access could help to reduce the opposition to biotechnology.

Paper 2 investigates an alternative psychosocial factor, cultural worldview, which has been underestimated or omitted when examining consumer acceptance of food biotechnology. Individuals' cultural worldviews were measured by a slightly modified version of cultural

cognition scale. Results suggest that individuals holding hierarchical (vs. egalitarian) and communitarian (vs. individualistic) worldviews tend to hold more positive attitudes and be more accepting of agricultural biotechnology.

Paper 3 suggests that *intermediary* food-related values and their relative importance to consumers have significant powers in explaining attitudes and choices about foods produced by means of nanotechnology. Consumers are heterogeneous in their food values, i.e., they place different importance on food value items such as naturalness, appearance, convenience, safety and novelty. Although Canadian consumers, on average, prefer not to use nanotechnology in sliced apple production, their preferences are heterogeneous. ‘Supporters’ of nanotechnology applied to agriculture and food production are those who consider ‘appearance’ is an important value to food purchase. By contrast, ‘opponents’ tend to emphasize the importance of ‘naturalness’ and ‘origin’.

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## Chapter 1 – Introduction

Advances in food technologies affect what and how people eat by offering foods with diverse characteristics. Consumers' attitudes towards food technologies, however, are not uniformly positive (Costa-Font, Gil and Traill 2008; Hu et al. 2004; Hu, Veeman and Adamowicz 2005; Lusk et al. 2005; Lusk, Roosen and Fox 2003). Non-expert consumers often do not view the scientific advances as experts do (Funk and Rainie 2015), not only because they have limited knowledge (Bieberstein et al. 2013; Cobb and Macoubrie 2004; Costa-Font, Gil and Traill 2008; Gaskell et al. 1999; Giles et al. 2015; House et al. 2004; McFadden and Lusk 2016), but also they form their technology perceptions based on a set of factors that are different than those of scientists (Slovic 1987; Slovic et al. 2007). The lay public learns about the science of agriculture and food mostly from media content such as television and the Internet (Agriculture and Agri-Food Canada 2014; Dahlstrom 2014), however, consumer acceptance of novel food technologies does not necessarily grow with more information and a greater level of familiarity. Even with exposure to the same balanced and unbiased information, people's food technology attitudes may fail to converge and become more polarized (McFadden and Lusk 2015; Kahan et al. 2009).

This thesis, consisting of three stand-alone but interrelated papers, aims to provide a better understanding of factors that motivate consumers' disparate assessments of novel food technologies. Breaking away from assumptions of fully rational decision-makers (i.e., who possess perfect information and cognitive capacity), insights of behavioural economics rather suggest that people are boundedly rational, with limited cognitive capacities to process complex information (Kahneman and Tversky 1979; Simon 1955; Simon 1956; Simon 1982; Tversky and Kahneman 1974). In particular, consumers' attitudes are very likely to be affected by '*inside*' individual factors, such as underlying human values or worldviews, as well as '*outside*' environmental factors, such as the strategies used to communicate information about food technologies (i.e., information framing).

Food technologies have advanced rapidly. For example, the first generation of agricultural biotechnology enabled scientists to develop crops that are resistant to insects, herbicides, diseases, or harsh growing conditions. The second generation focused on improving quality characteristics of food products, such as higher nutritional values, better taste, and longer shelf life (Rothstein et

al. 2014; Stewart and McLean 2005; Willmitzer 1999).<sup>1</sup> Nanotechnology, which deal with things at extremely small scales, has great potential to improve agriculture and food production. It could be used in nutrient supplements, food processing, and food packaging (Handford et al. 2014). For instance, nanotechnology could be used to develop food fortified with nano-sized nutrients that enhance nutrient absorption, or intelligent food packaging with nano-sensors that indicate the freshness of the food product inside the package (Duncan 2011; Ravichandran 2010).

Previous studies suggest that public perceptions of new food technologies differ by the particular technology format and the benefits offered. For example, consumer attitudes are typically more favorable if tangible and direct consumer benefits are provided from food technologies (Lusk, McFadden and Rickard 2015). Also, plant breeding methods that do not introduce foreign genes into plants are typically preferred than otherwise (Colson, Huffman and Rousu 2011; Hudson, Caplanova and Novak 2015).

Inspired by the regulatory approvals of the Arctic Apple<sup>2</sup>, which is a genetically modified apple variety that resists browning, this thesis explores consumers' acceptance of two tangible and concrete consumer-oriented food benefits: apple slices that are non-browning and enhanced with a greater level of antioxidants like Vitamin C. In addition, this study investigates consumers' perceptions of different food technologies used to achieve these apple characteristics, including gene editing (a.k.a., CRISPR-Cas9, which makes more precise and quick changes to existing plant genes), genetic modification (i.e., the transfer of plant genes from one organism to another), and nano-coating (i.e., immersing foods into coating solutions that contain nano-sized ingredients).

This thesis develops two versions of a consumer survey to collect data on attitudes and choice behaviours related to food biotechnology and nanotechnology. In total, 1608 Canadian consumers

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<sup>1</sup> Examples include golden rice that has been genetically engineered to contain higher levels of the vitamin A precursor beta-carotene, genetically modified tomatoes with improved aroma and taste achieved through a flavour-enhancing gene (Davidovich-Rikanati et al. 2007), and delayed-ripening bananas with extended shelf life (Elitzur et al. 2016).

<sup>2</sup> The non-browning Arctic apple has received regulatory approvals in both Canada and the U.S. for human consumption. See the Health Canada website: <http://www.hc-sc.gc.ca/fn-an/gmf-agm/appro/index-eng.php> for a full list of biotech foods approved in Canada, and the USDA-APHIS website: <https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/permits-notifications-petitions/petitions/petition-status> for a list of biotech crops approved in the U.S.

participated in this online study during the summer of 2016, with 804 completing the survey version focusing on biotechnology and the remaining 804 completing the survey version related to nanotechnology. An extensive survey data set is developed by collecting data on respondents' food technology perceptions, attitudes, and food choices. A choice experiment is incorporated in both survey versions, where respondents select their most preferred sliced apple products from a set of hypothetical and experimentally designed alternatives. The choice experiment allows understanding how consumers evaluate different novel apple characteristics and the technologies used in sliced apple production. Analyses of all three papers are based on data collected from this extensive survey, but each paper focuses on different research questions, thus using data from different survey sections.

Paper 1, presented in Chapter 2, explores the information framing effects by comparing two distinct information formats – logical-scientific vs. narrative – to communicate food biotechnology with consumers. Narratives (stories) are considered as a strong tool to communicate complex scientific topics with non-experts, since they are easier to understand, more engaging and persuasive compared to the logical-scientific information (Avraamidou and Osborne 2009; Bubela et al. 2009; Dahlstrom 2014; Norris et al. 2005). Using narratives has been shown to generate better science learning outcomes among students (Avraamidou and Osborne 2009; Glaser, Garsoffky and Schwan 2009; Norris et al. 2005) and also helps promote healthier behaviours such as increasing intentions to vaccinate (Betsch et al. 2011; Nan et al. 2015), reducing resistance to cancer prevention behaviours (Kreuter et al. 2007), and encouraging prevention of environmental risk (Golding, Krinsky and Plough 1992).

To the best of my knowledge, however, there exist no food studies exploring the effects of using narrative communication in shaping food technology acceptance. Previous studies of information framing effects suggest that the type (e.g., benefits vs. risks, or health, environmental vs. societal information), sequence (which information is presented first), and credibility of sources of information (e.g., government, food industry, or scientist) have significant impacts in attitude formation towards new food technologies (Cobb 2005; Fox, Hayes and Shogren 2002; Frewer et al. 1996; Frewer, Howard and Shepherd 1998; Li, McCluskey and Wahl 2004; Lusk et al. 2004; Marette et al. 2008; Markosyan, McCluskey and Wahl 2009; Roosen et al. 2011). The narrative format of information with which consumers may be more familiar, however, is omitted in these

studies which create information about food technologies using a uniform logical-scientific language.

In this paper, I deliberately develop information about food biotechnology in both logical-scientific and narrative formats. The logical-scientific information is written with a generalized and impersonal language while the narratives are written with a more vivid language. This study reveals a significant narrative effect; narratives (stories) about benefits arising from products developed through the application of biotechnology can induce greater changes in consumer attitudes and stronger acceptance of biotechnology, compared with information presented in a logical-scientific format.

Paper 2, presented in Chapter 3, addresses the question of whether public perceptions of biotechnology are an expression of underlying cultural worldviews. A set of psychosocial factors have been shown to have significant impacts on food technology perceptions, such as the feelings or emotions evoked by technology (Siegrist et al. 2007; 2008), trust in food industry or other institutions (Roosen et al. 2015), views on science and technology in general (Vandermoere et al. 2010; 2011), initial attitudes towards food technology (Frewer, Howard and Shepherd 1998), and the familiarity with technology (Bieberstein et al. 2013; Gaskell et al. 1999; House et al. 2004; McFadden and Lusk 2016). The influences of human values or worldviews, however, are underestimated or omitted in previous studies.

This paper measures consumers' cultural worldviews with two cultural cognition scales – 'Hierarchy-Egalitarianism (HE)' and 'Individualism-Communitarianism (IC)' (Kahan 2012). The HE scale captures attitudes towards social orderings based on explicit and stable individual characteristics, such as gender, race, wealth, and so on; while the IC scale reflects attitudes towards individual interests vs. the collective social welfare, i.e., which interests should be secured and by whom. The cultural cognition scales have been found to affect risk perceptions on diverse controversial topics, such as nanotechnology (Kahan et al. 2009), climate change (Kahan, Jenkins-Smith and Braman 2011), handgun use (Kahan et al. 2007), and vaccination (Kahan et al. 2010).

Most studies of human values or worldviews focus on their impacts on attitude formation, however, this study goes further in exploring how a cultural worldview impacts both consumer attitudes and food choice behaviours. Results suggest that a hierarchical worldview disposes consumers to hold

more positive attitudes and less resistance to food biotechnology, compared with an egalitarian worldview. On the other hand, a relatively individualistic worldview disposes consumers to hold more negative attitudes and weaker acceptance of biotechnology, as opposed to a communitarian worldview.

Paper 3, presented in Chapter 4, further explores the effects of human values on food technology perceptions, however, rather than focusing on more *abstract* human values (i.e., cultural worldviews in paper 2) this study examines the influences of *intermediary* values that specifically relate to food choices – food values. Public attitudes towards food nanotechnology have not become firmly established as research on nanotechnology in agriculture and food applications is still at an early stage and consumers currently have very limited knowledge about food nanotechnology (Giles et al. 2015). This study aims to investigate whether the relative importance people place on the list of food values can help explain their attitudes to and preferences for foods produced by means of nanotechnology.

In chapter 4, consumers' food values are measured with a slightly adapted version of food value scale developed by Lusk and Briggeman (2009), including naturalness, taste, price, safety, convenience, nutrition, tradition, origin, fairness, appearance, and environmental impact. As consumers may be different in their food values (i.e., which food values are most important to them), which in turn may induce differing choice behaviours, a set of choice models – a random parameter logit (RPL) model and a latent class model (LCM) – are estimated to capture different dimensions of preference heterogeneity among consumers. Results indicate that there exist three segments of consumers – supporters, doubters, and opponents of food nanotechnology – who are very heterogeneous in their food values. Also, variations in food values explain a significant amount of differences in perceptions and preferences for foods produced by nanotechnology.

In sum, as novel food technologies evolve rapidly, forming unbiased attitudes and making informed choices becomes even harder for consumers in such complex and uncertain conditions. This thesis deconstructs consumers' attitudes towards novel food technologies by exploring the reasons for the disparate attitudes and choice behaviours related to food biotechnology and nanotechnology. Each paper examines one particular attitude shaping factor, however, these factors may exert their influences either separately in their own competent areas or act in concert by complementing with each other.



The thesis explores effects of alternative ‘*inside*’ individual factors by examining whether attitudes to a controversial food technology is an expression of underlying and deep-rooted human values (i.e., cultural worldviews and food values), the effects of which have been omitted or underestimated in the existing literature. The thesis also explores the information framing effects (i.e., an ‘*outside*’ environmental factors) by comparing the effectiveness of two information formats – logical-scientific information vs. narratives – in shaping food technology acceptance. While the narrative effect has been identified in several other areas (e.g., science education and health communication), this represents the first attempt to examine information framing effects from narratives in the context of food choices.

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## **Chapter 2 – Exploring Information Framing Effects Through the Use of Narratives to Communicate Biotechnology with Consumers**

### **2.1 Introduction**

As the science behind agriculture and food production evolves very rapidly, explaining its benefits and risks to consumers becomes more difficult and challenging. The primary goal of science communication is to disseminate factual and unbiased knowledge and information, however, when communicating with consumers about novel food technologies (e.g., biotechnology) with which they are unfamiliar, *how* the information is presented could be as important as *what* information is presented.

Logical-scientific language is required for conducting rigorous science research and disseminating knowledge in peer-reviewed scientific journals. Food scientists, researchers, and experts are trained to use logical-scientific language, however, non-expert consumers are more familiar with an alternative format of information. Laypersons learn most scientific information, especially that related to food technologies, through media and social media, with television and the Internet have been identified as the top information sources (Agriculture and Agri-Food Canada 2014; Dahlstrom 2014). This media content, however, is characterized by the use of narrative formats in order to develop appealing news stories to compete for the attention of audiences.

This study contributes to the literature on the information framing effects by comparing these two information formats – logical-scientific vs. narrative – to communicate about food biotechnology with consumers. In particular, this study examines whether narratives (stories) about biotechnology result in consumer attitudes and choice behaviours that are different when using logical-scientific information.

Previous studies reveal significant information framing effects during food technology communication. For example, the type (e.g. whether solely benefit or risk information, or balanced information is provided) and order (i.e., the sequence of information presented) of information are found to influence consumers' attitudes formation towards various food technologies, such as irradiation (Fox, Hayes and Shogren 2002), biotechnology (Li, McCluskey and Wahl 2004; Lusk et al. 2004), and nanotechnology (Roosen et al. 2011; Cobb 2005). Most studies develop their own

sets of information on food technologies so that informational impacts can be identified by allocating participants into different information treatments. However, most, if not all, information developed in previous studies is written with a logical-scientific language. The narrative format, with which consumers are more familiar and are most likely to encounter in a real-life setting, is omitted in previous food choice studies.

The benefits of using narratives to communicate with laypeople about scientific knowledge, however, have been demonstrated in other areas such as science education and health communication. Compared with the traditional logical-scientific information, narratives (stories) are found to be easier to comprehend, more interesting, engaging and persuasive (Avraamidou and Osborne 2009; Dahlstrom 2014; Norris et al. 2005). Story-like materials are more efficient than traditional logical-scientific information when communicating environmental risk (Golding, Krimsky and Plough 1992), vaccination risk (Betsch et al. 2011; Nan et al. 2015), and reducing resistance to cancer prevention behaviours (Kreuter et al. 2007).

This study contributes to the literature on consumer acceptance of food technologies in three ways. First, it provides a more nuanced understanding of information framing effects by exploring the influences of using a unique information format – narratives – to communicate food biotechnology with non-expert consumers. Although narratives (stories) are the format that consumers are most familiar with, to the best of my knowledge, they are overlooked in previous studies on consumers' reactions to information and acceptance of food technologies. Second, this study deliberately develops logical-scientific and narrative information about biotechnology and provides this information to a representative sample of Canadian consumers under different conditions. The logical-scientific information was written in the scientific style of the passive voice with generalized and impersonal language. In contrast, narrative information was written in a more lively and vivid personal style. As such, this study allows directly comparing the effects of using these two distinct information formats to communicate biotechnology with consumers. Finally, while many previous consumer studies focus on the productivity or environmental benefits of biotechnology (e.g., reduction in pesticide use), this study aims at understanding consumer responses to biotechnology that enhances food attributes with a more tangible and direct consumer benefits (i.e., apple slices that resist browning and contain a greater level of antioxidants such as Vitamin C).

This chapter is organized as follows. Section 2.2 provides a review of both theoretical and empirical studies on information framing effects and narrative communication, which inform the current study. Based on the review, a set of testable hypotheses are developed for this study in section 2.3. Data on consumers' attitudes and food choices are collected from an extensive online survey. Section 2.4 describes the design of the survey, in particular, how logical-scientific and narrative information about biotechnology is deliberately developed for this study. Section 2.5 presents the design of the choice experiment that is included in the survey to capture consumers' food choice behaviours regarding sliced apple products. The choice models used for estimation, the multinomial logit and the random parameter logit models, are specified in section 2.6. The estimation results are presented in section 2.7. Section 2.8 summarizes the main findings on the narrative effects and concludes.

## **2.2 Literature Review**

This section begins with an introduction of information framing effects and use of information framing in analyses of consumer attitudes towards novel food technologies. Then, a unique format of information framing – narrative communication – is introduced. This section describes what constitute narratives and discusses the role of narratives in science communication. A sample of empirical studies on narrative effects is also be reviewed. Finally, a set of hypotheses are developed in section 2.3 based on reviewed theories and studies.

### **2.2.1 Information Framing Effect**

Since its introduction to agriculture and food production in the early 1990s, biotechnology has evolved in developing new tools to improve crops and food products. The first generation of agricultural biotechnology was mostly applied to significant commodity crops such as corn, cotton, and soybeans that are resistant to certain pests, herbicides, and diseases. The newer generation of biotechnology concerns improving product quality characteristics that are more tangible to consumers, such as higher nutritional content and greater convenience (Stewart and McLean 2005).

Despite the promises of biotechnology, it has received limited acceptance among the general public, who possess low awareness and understanding of the technology, with concerns expressed about potential risks imposed on the environment, health, and society (Costa-Font, Gil and Traill 2008; Lusk et al. 2005). Therefore, scholars posit that more information and education are needed

to shrink the opinion gap between the public and the majority of scientists who believe agricultural biotechnology is generally safe for human consumption and the environment (Allum et al. 2008; Miller 1983). This ‘knowledge deficit’ hypothesis, however, overlooks the characteristics of audiences and how they would process and make sense of the furnished information.

Insights from behavioural economics and psychology suggest that individuals are boundedly rational, with limited cognitive capacities when processing complex information (Kahneman and Tversky 1979; Simon 1955; Simon 1956; Simon 1982; Tversky and Kahneman 1974). As such, how information is framed and presented to audiences matters in shaping attitudes and behaviours. Information framing effect is the cognitive bias identified by Tversky and Kahneman (1981) in their seminal work that changing frames of decision problems (e.g., whether the probabilities and outcomes are presented in terms of gains or losses) can shift individuals’ preferences and decisions.

Empirical studies of public acceptance of novel food technologies also support the framing effect, i.e., how benefit and risk information about a certain novel food technology is communicated with the public matters for its acceptance. For example, the type (e.g. whether solely benefit or risk information, or balanced information is provided), order (i.e., the sequence of information presented), and the source credibility (e.g., government, food industry, scientist) of information are all considered as having influences on attitudes towards novel food technologies (Cobb 2005; Fox, Hayes and Shogren 2002; Frewer et al. 1996; Frewer, Howard and Shepherd 1998; Li, McCluskey and Wahl 2004; Lusk et al. 2004; Marette et al. 2008; Markosyan, McCluskey and Wahl 2009; Roosen et al. 2011).

It is not uncommon that participants in a survey or experimental study are exposed to some ‘new’ information about food technologies prepared by researchers. The particular type of information provided to participants can influence their attitudes. For example, Fox, Hayes and Shogren (2002) examined how alternative frames of food irradiation affect U.S. subjects’ willingness-to-pay (WTP) for a pork sandwich irradiated to control the parasite *Trichinella* as an exchange for an endowed conventional pork sandwich. Their results indicated that solely favourable (unfavourable) information would increase (decrease) participants’ WTP for an irradiated pork sandwich, whereas when balanced (both pro- and anti-) information was provided, the negative information overwhelms the impact of positive information and resulted in a reduction in WTP values. Also, the dominance of negative information would persist even when the source of such negative

information was identified as non-scientific and provided by non-experts such as a consumer advocacy group.

To investigate the differential impacts of framing on public perception of nanotechnology, Cobb (2005) compared three nanotechnology frames: specific nanotechnology risks, benefits, and general merits of science. Results of a telephone survey of 1536 U.S. adults revealed that the frames of specific benefits and risks of nanotechnology are more influential than the general frames on merits of science, and the positive frames on specific benefits are similarly as powerful as negative frames in affecting attitudes towards nanotechnology.

Lusk et al. (2004) found that one-sided information about the potential benefits of biotechnology can significantly decrease the monetary compensation needed by participants to consume genetically modified (GM) food in an experimental auction. More importantly, the effect of positive information varied by types and locations. The experimental auction was conducted in three U.S. states (California, Florida, and Texas) and two European countries (England and France). Each participant was provided with one of three information types – information on biotechnology benefits to the environment, health, or developing countries – and then was asked to indicate the minimum amount of money they are willing to accept to exchange their non-GM cookie for a chocolate cookie containing genetically modified ingredients. Results indicated that three information types have differing effects on the average bids, for example, in Texas, environmental information had a greater impact in reducing the compensation needed for consuming a GM cookie than the developing country benefits information.

The sequence of information provided to individuals can also have significant impacts on attitudes and behaviours. For instance, Marette et al. (2008) examined the impact of health information on choices between a relatively ‘healthy’ fish (sardines) and a relatively ‘less healthy’ fish (tuna). A sample of 115 French women of childbearing age were provided with information on both risks (methylmercury) and benefits (omega-3 fatty acids) of two fish choices shown in different orders. Results showed that the sequencing order information on risks and benefits has a significant impact on choice behaviours: presenting benefits before risks is more efficient in inducing healthier fish choices as the benefit information is more likely to be absorbed.

Another example is given by Roosen et al. (2011), who evaluated the impact of information order on willingness-to-pay for nano-juice, a hypothetical orange juice fortified with vitamin D using

nanotechnology. 143 German participants were provided with different types of balanced information (i.e., health, societal, and environmental impacts of nanotechnology) about nanotechnology shown in three experimentally manipulated orders: an imposed order of information by the experimenter, a chosen order by participants themselves, and a chosen order by participants after a group discussion. Results suggested that the first information revealed in a forced order group has no significant impact on reducing WTP, whereas the first information chosen by participants has the strongest impact on reducing WTPs and discussion has no further impact. In addition, regardless of the order of presentation, information about the health impacts of nanotechnology has the greatest impact in reducing WTP for the nano-juice, while environmental and societal information has no significant impacts. The study provides a good example of how both type and order of information can influence attitudes towards novel food technologies.

In addition to the information type and order, the perceived quality of information and its source credibility have also been found to influence attitudes and behaviours related to food technology. Many studies have shown that for food science and technology, farmers, environmental groups and scientists are considered as more trustworthy than the government, biotechnology industry and social media (Costa-Font, Gil and Traill 2008; Health Canada 2016). For example, Frewer et al. (1996) find that, for food-related information sources, industry and government are often not trusted by the UK public, whereas consumer organizations, high quality newspapers or television programs, and medical professionals are highly trusted. The authors also reveal that the trust and credibility of an information source is determined by the public's perception of the positive source characteristics, such as accuracy, knowledge, accountability and concern with public welfare. Whereas, distrust in the information source is linked with perceptions of distortion of information by the source and its history of providing erroneous information. Frewer, Howard and Shepherd (1998) further reveal that information source credibility is an important determinant of effectiveness when communicating genetic engineering to the UK public. More importantly, admitting scientific uncertainty (i.e., acknowledging that scientific process is not absolutely risk free) could increase the credibility of information provided, and thus reduce the opposition to genetic engineering among UK respondents.

The proceeding sampling of literature suggests that, in an experimental setting, information matters for shaping attitudes and behaviours related to novel food technologies. More importantly, *how* the information is presented could be as important as *what* information is presented.

Most of the aforementioned studies have developed their own sets of information on food technologies so that informational impacts can be identified by allocating participants into different information treatments. In these studies, unbiased information was deliberately developed to reflect the best available scientific knowledge and facts. Also, information was written in a logical-scientific language such that it appears to be scientific and professional. However, the information format and language adopted in previous studies are very different than that with which consumers are familiar.

The next section describes a unique information format – narratives – that laypeople are most familiar with and likely to encounter when learning about food science and technology. The properties and advantages of using narratives to communicate science are also discussed.

### **2.2.2 Narrative Communication**

In a real life situation, the media is the primary source from which consumers get most of their information about new food technologies. According to the Science and Engineering Indicators 2016 (National Science Board 2016), the primary sources Americans used to learn about science and technology are: the Internet (chosen by 46.57% of sampled respondents), television (28.32%), and newspapers (5.92%). Radio, magazines, books, government agencies, family and friends/colleagues as sources for science information reached 18.48% when combined. Among the people who go online for science information, about half (45%) said that they use online news sites such as online newspapers and magazines, 36% said they use a search engine such as Google to seek information, only 8% said they rely on a science-focused site, and the rest go to some other places on the Internet which could be social media accounts and online blogs. Similarly, television and radio reports, newspaper and magazine stories, and the Internet are among the top information sources Canadians rely upon when learning about food and nutrition issues (Agriculture and Agri-Food Canada 2014).

As people rely on media content for information about science and technology, efforts have been made to understand the impact of media frames on consumers' perceptions. Besley and Shanahan

(2005) show that attention to entertainment television and science news in television, has a significant positive impact on consumers' support for agricultural biotechnology. However, images of science and technology are generally portrayed as negative by the media, in particular, the sensationalized narratives in television often distort science and inhibit public understanding (Nisbet et al. 2002). The negative frames of biotechnology dominating mass and/or social media have been criticized as one of the driving forces behind the public opposition to agricultural biotechnology (Marks and Kalaitzandonakes 2001; McCluskey and Swinnen 2004; McCluskey and Swinnen 2011; McCluskey, Kalaitzandonakes and Swinnen 2016; Nisbet et al. 2002).

Unlike scientists, whose primary goal is to discover and disseminate scientific truth and facts, the media and other organizations such as activist groups and government agencies have their own interests when reporting science news. These organizations may be incentivized to focus on negative and emotional news stories regarding food technology as they aim to attract their audiences' attention, donations and funding (McCluskey and Swinnen 2004; McCluskey and Swinnen 2011; McCluskey, Kalaitzandonakes and Swinnen 2016).

An explanation for the significant media impact on public perceptions of new food technologies is given by Lusk, Roosen and Bieberstein (2014). The media frames food technology in an emotional way and repeats messages such that the issue becomes readily available in people's memory, which is known as the availability heuristic.

Of particular interest here is the frame used by media content when describing science and technology. A major characteristic of media content is the use of narratives (i.e. stories), as journalists have to balance their dual goals of reporting accurate information while attracting their target audiences' attention (Dahlstrom 2014). The principal practice for developing science news is to personify abstract scientific concepts for dramatic storytelling, and other aspects of information such as accuracy are often ignored (Dahlstrom 2014). As consumers rely heavily on media for information about science and technology, which is already biased towards using narratives, narratives become the major format of information communication about science and technology received by consumers.

To communicate science to the public, the media adopts a different frame than scientific researchers whose objective is to provide accurate rather than attractive messages. Such divergence of information framing about new food technology inspires this study, which aims at providing a



more nuanced understanding of information framing effects on consumers' perceptions and preferences.

Science research underscores the importance of accuracy and scientific rigor during its data collection, experiment implementation, and results interpretation. However, the logical-scientific information is often abstract, technical and 'cold' when communicating to non-expert audiences such as consumers. By contrast, narratives or stories of science communication are more accessible (i.e., via media contents) and using language with which laypeople are more familiar.

A review of previous food technology studies informs that communication and information are important factors in shaping attitudes and behaviours, however, there is an absence of research understanding the effects of different information formats – logical-scientific vs. narrative – on individuals' perceptions about novel food technology and their food choices. The vast majority, if not all, of the information provided in experimental settings such as those reviewed earlier are in the logical-scientific format, whereas the primary format of science information consumers encounter within everyday life is the narrative. Therefore, this paper fills a knowledge gap by investigating if these two information frames generate differing consumer attitudes and preferences.

Narrative has been defined as a distinct communication format, however, there exists no such definition of a narrative that is universally accepted by scholars as it can take various forms. Different sets of factors have been proposed to define narratives depending on specific research focuses and interests. The most general definition of narrative is given by Smith (1980, p.232): "we might conceive of narrative discourse most minimally and most generally as verbal acts consisting of *someone telling someone else that something happened*". Based on this general statement, Norris et al. (2005) outlined the elements that feature in narratives, such as the narrator, reader, event-tokens and particular structure of narratives. A more tangible definition is proposed by Hinyard and Kreuter (2007, p.778), who define a narrative as "any cohesive and coherent story with an identifiable beginning, middle, and end that provides information about scene, characters, and conflict; raises unanswered questions or unresolved conflict; and provides resolution". Dahlstrom (2014, p.13614) provides a fairly standard definition of narrative communication, which is "a particular structure that describes the cause-and-effect relationships between events that take place over a particular time period that impact particular characters". As such, the three

essential factors – causality, temporality, and character – determine the narrativity of the information.

Examples of narratives include news stories, anecdotes, entertainment television programs and interpersonal conversations (Dahlstrom 2014). This study is mostly concerned with using written stories to communicate new food technology with consumers, thus the narrativity of the message is reflected by the character (a mom with two children), temporality (some past time, i.e., last week, when the family tried out a new apple variety), and causality (the story depicting how this family encountered the new apple variety produced by novel food technologies and what their reactions are to this apple).

Narratives are often contrasted with logical-scientific communication. Compared to narratives, logical-scientific information is usually expository, argumentative, interpretive, descriptive, statistical, and technical (Dahlstrom 2014; Norris et al. 2005). Logical-scientific information aims to define propositions or to explain a list of facts, whereas narratives aim to explain a series of causally linked events that unfold over time (Norris et al. 2005).

Dahlstrom (2014) summarized three major differences between the logical-scientific and narrative communication of science: direction of generalizability, reliance on context, and standards for legitimacy. The logical-scientific information aims to provide general facts of a matter, thus the use of logical-scientific information requires a deductive reasoning, understanding its content is context-free, and the legitimacy of the message depends on its accuracy. By contrast, the narrative information aims to provide descriptions of particular personal experiences, thus the use of narrative information requires inductive reasoning, understanding of its content is context-dependent, and its legitimacy depends on the verisimilitude of the message.

Narratives represent the default mode of human interaction and make up most of daily conversations. Thus, people are more familiar with this type of communication and feel more comfortable when receiving communication about complex issues. By contrast, as an alternative text genre, logical-scientific information usually involves explaining abstract concepts or propositions using vocabulary and an expository structure with which people have less experience. Therefore, narratives are more likely to activate certain emotional and cognitive effects that logical-scientific information are unable to provoke, and hence have profound influences on beliefs and real-world decisions.

The differences between narrative and logical-scientific communication are rooted in dual cognitive systems. Behavioural economists and psychologists point out that humans possess two systems of cognitive reasoning, one is affective, intuitive, and fast, while the other, deliberative, logical, and slow (Chaiken 1980; Epstein 1994; Evans 1984; Kahneman 2011; Petty and Cacioppo 1986; Sloman 1996; Stanovich and West 2000; Strack and Deutsch 2004). Information framed in logical-scientific and narrative formats is likely to engage different cognitive pathways. For example, encoding science-based arguments requires the systematic and logical pathway, whereas encoding situation-based exemplars requires the affective and narrative pathway (Dahlstrom 2014). Neuroscientist Zak (2015) even finds that compelling narratives can provoke certain brain areas and help releasing certain neurochemicals in the brain, which in turn influence individuals' attitudes and behaviours. However, such psychological effects are not observed for 'flat' or 'plain' messages.

Narratives have been suggested as intrinsically persuasive, and thus have the ability to shape beliefs and change minds that are rather persistent. The persuasiveness of narratives depends on the extent to which individuals can be narratively transported. Narrative transportation is the mental process in which narrative readers empathize with the characters, imagine they are experiencing the narrative plot themselves, and thus temporarily lose their track of reality and modify their perceptions (Van Laer et al. 2014).

To the best of my knowledge, there exist no studies exploring the effect of using narratives to communicate food technologies with consumers. Nevertheless, the narrative effect has been revealed in a range of other contexts such as health communication and science education. Compared with logical-scientific information, narratives are found to take a shorter time to read, are easier to be understood, more interesting, engaging, persuasive, and hence their content is more likely to be memorized and recalled at a later time (Avraamidou and Osborne 2009; Dahlstrom 2014; Norris et al. 2005).

Using narratives or story-like materials in science teaching and education could generate better learning outcomes (Avraamidou and Osborne 2009; Glaser, Garsoffky and Schwan 2009; Norris et al. 2005). Also, narratives are found to help communicate health-related issues and promote healthy choice behaviours. For example, compared with traditional scientific and technical materials, narratives or emotional stories have shown to be more efficient in communicating

environmental risk (Golding, Krimsky and Plough 1992), vaccination risk (Betsch et al. 2011; Nan et al. 2015), and reducing resistance to cancer prevention behaviours (Kreuter et al. 2007).

Golding, Krimsky and Plough (1992) reveal that a narrative is more efficient in communicating environmental risk. In the experiment, the authors developed two series of newspaper articles on radon published in two different communities. The technical series presented authoritative and factual risk information about radon, and the information was written in a scientific style with passive voice and impersonal language. The narrative risk information was written in personal style depicting the dialogue between a fictitious story character (a mother with two children) and her neighbor and doctor, and how the character made decisions about radon testing and mitigation. Results indicate a stronger narrative effect than the technical information in shaping perceptions and knowledge of radon risk, and intention regarding preventive behaviours.

Another example is given by Betsch et al. (2011), who studied the narrative effect on vaccination decisions. In an online bulletin board setting, respondents were provided with either statistical information or narratives about the occurrence of adverse vaccine events. Authors also varied features of the narratives in terms of incidence rate (2/10 vs. 4/10 narratives reporting adverse events) and emotionality of narratives (high vs. low emotionality). Results showed that narratives have greater impacts than statistical information on the perceived risk of side-effects and vaccination intentions. In particular, narratives reporting greater incidence rate of adverse events and shown in higher emotionality had a greater impact on increasing perceived vaccination risk and reducing vaccination intentions.

There are also examples of narrative effects when communicating health-related issues, such as cancer, anticoagulant medication, and human papillomavirus (HPV) vaccination. Kreuter et al. (2007) suggest that narratives can help address cancer prevention and control issues by reducing resistance to prevention behaviors and health messages, facilitating processing of cancer information, providing social connections for those affected by cancer, and addressing emotional issues after a cancer diagnosis. Mazor et al. (2007) compared the relative impact of three versions of a video – patients' anecdotes, statistical evidence, and both – on education about anticoagulant medication. Results show that using patient anecdotes is more effective than statistical information in educating patients about anticoagulant medication by promoting knowledge and lab testing. Similarly, Nan et al. (2015) suggested that the hybrid format of evidence, which contains both

statistical information from the CDC (Centers of Disease Control) website and narrative messages in news articles describing personal experiences with HPV, is more effective, than using statistical or narrative information alone, in eliciting greater risk perceptions about HPV and greater intention to vaccinate against HPV.

Given the effectiveness of the narrative communication format as reviewed, there are also ethical concerns that researchers need to consider before using a narrative to communicate science to non-expert audiences, as narratives are intrinsically persuasive and their impacts are difficult to counter (Dahlstrom and Ho 2012). The ‘truth’ of logical-scientific communication is judged by its accuracy, while the ‘truth’ of narrative communication is by its verisimilitude to the situations, therefore, the narrative effect is difficult to counter by facts (Dahlstrom 2014). According to Dahlstrom and Ho (2012), the first ethical question that needs to be considered when communicating science within social controversies is whether the goal of narrative communication is to promote a preferred outcome (persuasion) or to promote a greater engagement and autonomy within the science debate (comprehension). Both could be ethical depending on the circumstances. Other ethical considerations include the levels of accuracy maintained in a narrative and the potential violation of the normative expectations of science communication by using narratives.

Given the ethical concerns and challenges of using narratives to communicate science with the public, especially when the topics are controversial, questions like *whether* it is appropriate to use narratives in science communication could be raised (Dahlstrom and Ho 2012). However, a more relevant question would be *how* to appropriately and effectively use narratives in communication as “other communicators within the issue will likely use narratives and it would be unethical not to use narrative and surrender the benefits of a communication technique to the non-expert side of an issue” (Dahlstrom 2014, p.13617).

Despite the merits of narrative communication, such as greater comprehension, engagement and persuasiveness, and the documented effectiveness when teaching science and communicating health issues, this information format has been ignored by studies on acceptance of food technologies. This study aims to fill this gap by investigating whether a narrative effect exists when communicating agricultural biotechnology with consumers.

## 2.3 Study Hypotheses

Based on the preceding review of theoretical and empirical work on information framing and narrative communication, a set of hypotheses are proposed. This study aims to examine the effect of narratives on shaping consumers' attitudes and choice behaviours related to food biotechnology. Information about biotechnology was developed in both logical-scientific and narrative formats, with each format either passively or voluntarily accessed by respondents depending on assignment to an information condition. After information exposure, respondents are asked to evaluate the quality of information they read, to answer a set of attitudinal questions about food biotechnology, and to make a series of food choices in a choice experiment. Information formats are expected to have significant impacts on perception and choice behaviour, as such I hypothesize the following:

**H<sub>1</sub>:** Information about food biotechnology shown in logical-scientific and narrative formats differs in quality characteristics including easiness to understand, persuasiveness, trustworthiness, source credibility, and factualness.

The quality of provided information shown in different formats was evaluated by respondents immediately after information provision. Respondents were asked to indicate to what extent they think the information was “easy to understand”, “persuasive”, “trustworthy”, “from a credible source”, and “factual and unbiased”. Based on reviewed studies, it is expected that respondents will rate narrative information about biotechnology as easier to understand and more persuasive, while logical-scientific information as more trustworthy, credible and factual.

**H<sub>2</sub>:** Information communicated in different formats will induce different degrees of attitudinal changes.

Respondents were asked to evaluate food biotechnology both before and after being exposed to information shown in different formats. For example, respondents indicated whether they think making ‘a single precise change to a plant’s existing genes’ (i.e., gene editing technology) when producing crops or foods is *natural*, *ethical*, and *safe*. After reading logical-scientific or narrative information about biotechnology, respondents assessed the gene editing technique again by answering a set of similar rating questions. As such, changes in attitudes towards gene editing within each information condition can be measured. It is expected that, compared with logical-

scientific information, narratives will generate greater attitudinal changes, as they are more persuasive and easier to comprehend.

**H<sub>3</sub>:** Information provided in different formats will have different impacts on preferences for and valuations of novel food traits and technologies.

Respondents made a set of choices about sliced apple products in a choice experiment, which allows examining their preferences for different novel food traits (i.e., non-browning and antioxidant-enhanced) and technologies (gene editing, genetic modification, and edible coating). As the information developed in this study is a ‘one-sided’ statement emphasizing the benefits of biotechnology, it is expected that narratives will generate stronger acceptance of novel technologies, compared with logical-scientific information.

To test these hypotheses, consumer data were collected from an Internet survey administered to 804 Canadian adults in 2016. The next section describes the design of the online survey, and especially discusses how the logical-scientific and narrative information about biotechnology was developed for this study.

## **2.4 Survey Design**

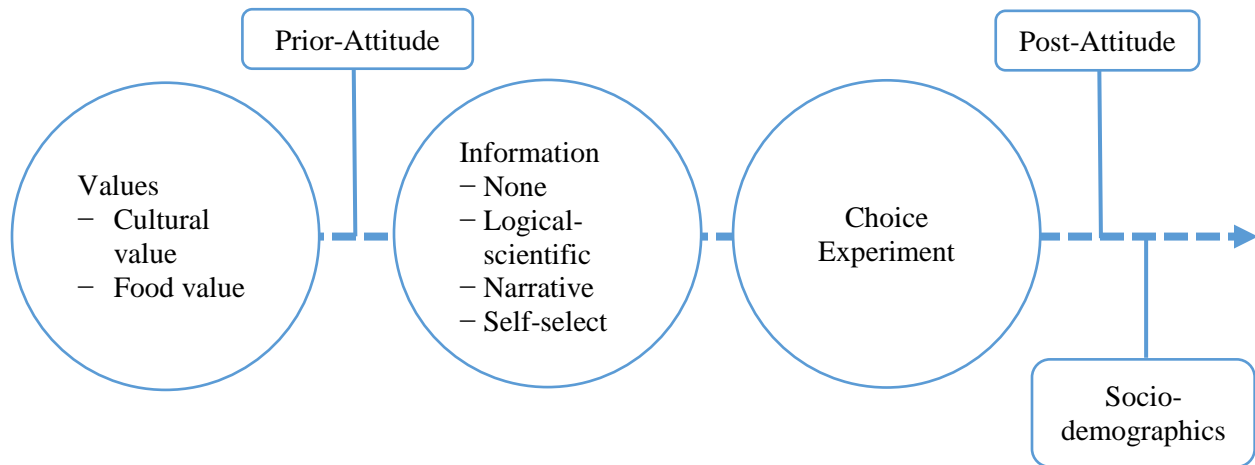
Data for this thesis research, which consists of three separate papers, were collected through a nationwide online survey administered to a random sample of 1608 Canadian adults in the summer of 2016. Section 2.4.1 presents the survey outline. Section 2.4.2 describes the characteristics of sampled respondents. Section 2.4.3 explains how different information material about food biotechnology was developed for this study.

### **2.4.1 Overview**

Two versions of the survey were developed to understand public perceptions of novel food technologies. One focuses on food biotechnology, and the other, food nanotechnology (see Appendix A and B respectively for the complete versions of each survey instrument). The two versions – food biotechnology survey (hereafter ‘Bio’) and food nanotechnology survey (hereafter ‘Nano’) – are almost identical in their layout, question wording and length.

Both online surveys consist of three main sections (i.e., human values, information conditions, and a choice experiment), a set of attitudinal questions (i.e., both prior to and after the information

provision), as well as questions related to respondents' demographic and socio-economic characteristics. Figure 2.1 presents an outline of the survey content. Both versions share the same survey design.



**Figure 2.1 Outline of Survey Design**

The first survey section collected information on respondents' cultural worldviews and food values. Before being exposed to any survey questions or information on novel food technologies, respondents were asked to indicate their levels of agreement or disagreement to 12 cultural value items developed by Kahan (2012) (see section 3.4.1 for more detail as Chapter 3 examines influences of cultural values on attitudes towards food biotechnology) and 11 food value items developed by Lusk and Briggeman (2009) (see section 4.4 for more detail as Chapter 4 examines whether perceptions of food nanotechnology are an expression of underlying food-related human values).

The second main survey section, 'information', is the focus of this chapter, and more detail is provided in section 2.4.3. In brief, each respondent was randomly assigned to one of four information conditions, including: (1) 'no additional information (control)', in which respondents received no additional information about food technologies, except for the basic introductory information that all respondents received regardless of information conditions; (2) a 'logical-scientific' condition, where respondents were presented with additional information about food technologies, and the information was developed on the basis of scientific facts and written with a relatively technical and impersonal language; (3) a 'narrative' condition where, in contrast with



the ‘logical-scientific’ condition, the equivalent information was provided but written with a relatively more vivid language and in a story-telling context; and (4) a ‘self-selection’ condition, where respondents were allowed to select one piece of information they prefer to read from four sources available: Health Canada, The Royal Society of Canada, a consumer blog post, and a science journalist’s article published in the Globe and Mail. The first two information sources were presented in the logical-scientific format, and the latter two were narratives (see Appendix A section [Information Conditions] for the full scripts of the information treatments).

As a result, except for those assigned to the ‘no additional information (control)’ condition, each respondent is passively presented with or actively chooses a piece of information about food technology shown in either a logical-scientific or a narrative format. This between-subject design allows exploring the information framing effects, especially examining whether different information formats, logical-scientific vs. narrative, can yield differing food technology attitudes and choice behaviours. More detail on the information conditions is presented in section 2.4.3.

Immediately after the information provision, respondents were asked to make a series of food choices in a choice experiment which is the final main section of the survey. In the choice experiment, respondents were asked to choose between a set of 500g bags of pre-packaged apple slices that vary in four food features: (1) *appearance* of apple slices, apples can turn brown in minutes after being sliced or resist browning for a long time; (2) *health benefit*, sliced apples are enhanced with higher levels of dietary antioxidants like Vitamin C or contain only a regular amount of antioxidants; (3) *production or processing method*, the aforementioned two novel apple characteristics, non-browning and antioxidant-enhanced, are introduced by food technologies – gene editing, genetic modification, and edible coating in the ‘Bio’ survey, or nano-coating and conventional coating in the ‘Nano’ survey. Apples produced by a conventional method will not possess either of the two novel characteristics; and (4) the retail *price* for a 500g bag of apple slices.

Each respondent made 6 choices in the experiment. By observing choices made in the experiment, researchers can understand how people value and make trade-offs between different food attributes included in this study. The development of the choice experiment, including the selection of attributes and levels, the efficient experiment design, and the blocked choice design are discussed in more detail in section 2.5.

Additional to the three core sections, the online survey also includes questions related to food technology perceptions and attitudes. One set of attitudinal questions were asked to respondents before the information conditions ('Prior-Attitude'), another set of attitudinal questions were asked after respondents were exposed to information conditions and completed the choice experiment ('Post-Attitude'). Data on respondents' demographic and socio-economic characteristics were also collected before they exited survey.

### **2.4.2 Sample**

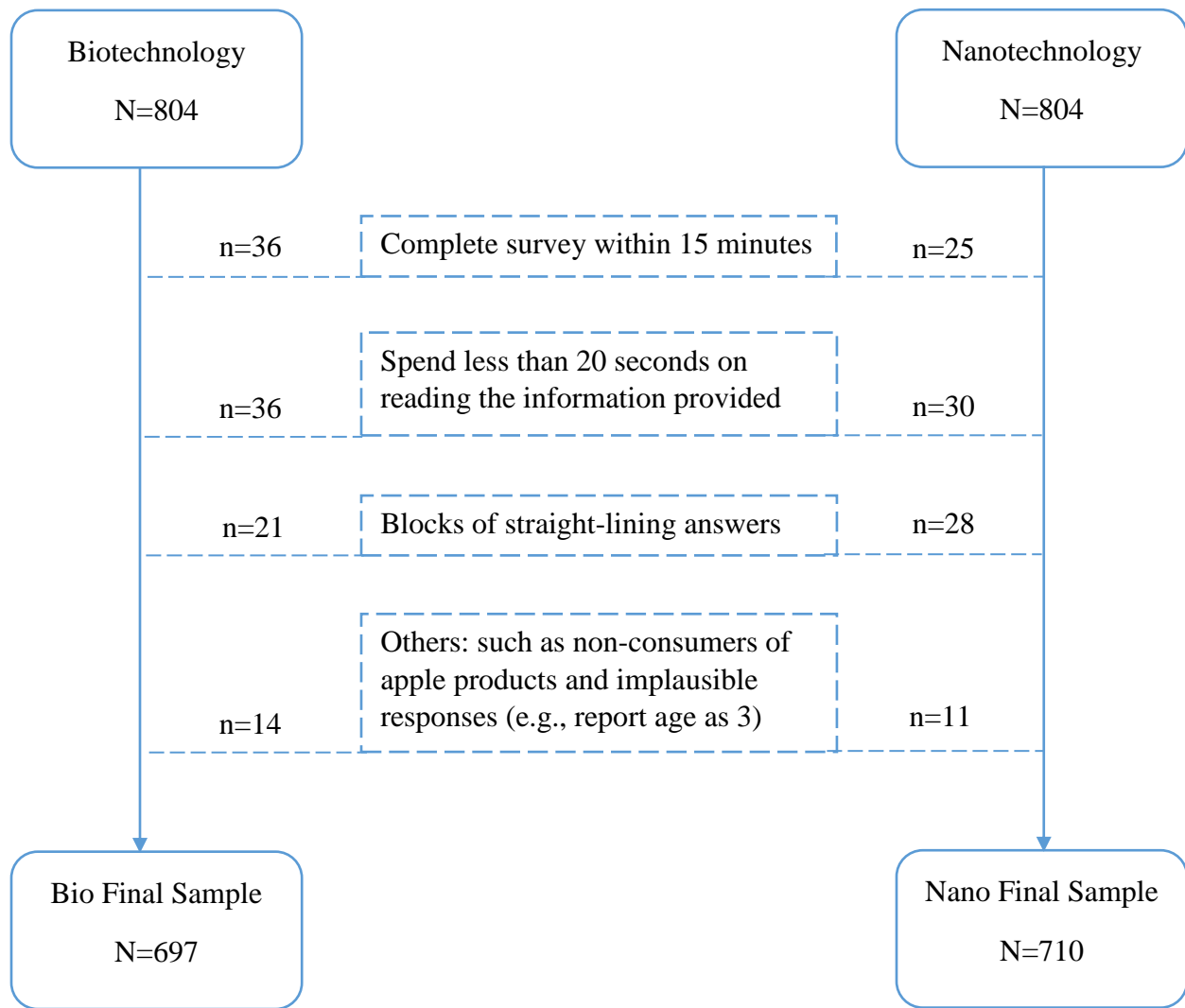
A total of 1608 Canadian adults were recruited into the web-based survey conducted between July and September 2016.<sup>3</sup> Only subjects who indicated they currently reside in a Canadian province or territory, and who indicated they were the primary grocery shopper (responsible for at least 50% of food purchases) in the household were allowed to participate in the study (see Appendix A or B section [Screener Questions]). The average time spent to complete the survey was approximately 40 minutes. As a means to incentivize participation, respondents could enter into a draw to win one of two prizes of \$500 once they completed the survey. Once they had agreed to participate into the study, subjects were randomly assigned to one of two survey versions, with 804 respondents completing the 'Bio' survey, and the remaining 804 respondents completing the 'Nano' survey. Analyses in this chapter rely on data collected from the 'Bio' survey only, and the 'Nano' survey data are analyzed in Chapter 4.<sup>4</sup>

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<sup>3</sup> This survey study received ethics approval (BEH# 16-131) from the University of Saskatchewan Behavioural Research Ethics Board on May 04 2016. The online survey was conducted via the Social Sciences Research Laboratories (SSRL) at the University of Saskatchewan. The survey was hosted by and programmed using Qualtrics, administered by the SSRL, and respondents were recruited through Probit, which is a third party vendor who facilitate direct contact with the participants. Probit recruits its panel members exclusively through random digit dialing methodology. Probit is contracted by the SSRL to obtain a representative sample of participants in any province throughout Canada.

<sup>4</sup> I attempted to explore the informational effects in the "Nano" dataset by conducting similar analyses included in this chapter. It is found that different information frames for nanotechnology (i.e., logical-scientific and narrative) fail to generate differing attitudes and choice behaviors in the "Nano" dataset (in the interests of brevity, those results are not presented here). Further research could examine whether the narrative effect differs between different food technology contexts. For example, it would be interesting to understand whether the narrative effect is stronger (or weaker) for food technology with greater levels of public awareness and familiarity.

To ensure the quality of data, responses were excluded from the study if it appeared that respondents did not pay enough attention on completing the survey. For example, a survey timer allowed to identify respondents who sped through the survey, finishing it within less than 15 minutes, as 15 minutes is considered the minimum time duration needed for reading all questions and providing serious responses. Responses were also excluded if respondents spent less than 20 seconds on reading the information provided in different information conditions. Further, since the survey contained a considerable number of rating scale questions, responses were removed if a large amount of straight-lined answers were identified (i.e., subjects rush through the survey by clicking on the same place on a rating scale for a set of questions). In the choice experiment respondents were asked to choose between a set of pre-packaged apple slices, thus non-consumers of apple products were excluded from study. Respondents reported unreasonable answers, e.g., reporting age as 3, were also removed from the analyses. Figure 2.2 shows the sequential criteria applied to data screening as well as the numbers of respondents removed from both survey versions. The final ‘Bio’ dataset consists of 697 respondents with 4182 choice observations, and the ‘Nano’ dataset consists of 710 respondents with 4260 choice observations.



**Figure 2.2 Screening of Sample**

Table 2.1 summarizes the characteristics of the sampled respondents in both survey versions, and a comparison with the 2011 Canadian Census statistics. The characteristics of respondents retained in the sample are also compared with those of respondents excluded by the screening criteria, however, no systematic differences between these two groups are identified.<sup>5</sup>

Within both the ‘Bio’ and ‘Nano’ dataset, the same percent of respondents (81%) chose to complete the online survey in English and the remaining 19% in French. The sample for both

<sup>5</sup> Two-sample *t* tests are used to determine whether means in ‘Bio’, ‘Nano’, and ‘Removed’ dataset are significantly different. It is found that, at a 1% significance level, all differences between means are insignificant.

survey versions is fairly representative of the Canadian population. About half (47% in ‘Bio’ and 45% in ‘Nano’) respondents are male and the geographic distribution of respondents across provinces and territories closely matches the national distribution. This sample, however, represents an older, better educated, and higher-income population relative to the Canadian average.<sup>6</sup>

The median education level for both survey versions is a university degree and the median household income falls in the range of \$80,000 to \$124,999. Both levels are higher than those of the average Canadian. Samples with higher education and income levels are often obtained in online data collection since these people are more likely to get access to the Internet (Szolnoki and Hoffmann 2013).

The mean age of sampled respondents is 55 in the ‘Bio’ survey and 54 in the ‘Nano’ survey, somewhat higher than that of Canadian adults. A possible explanation for an older sample is that only the primary grocery shoppers in households are allowed to participate in the study, as such younger respondents (i.e., age group 18-24) are less likely to participate. Another possible reason for the older sample is the amount of time needed to complete survey (i.e., approximately 40 minutes). Older respondents may be more patient to complete such a large survey.

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<sup>6</sup> There exists no significant difference in sex and geographic distribution between the survey data and 2011 census statistics. However, the differences in age, education, and income between survey and census statistics are significant at 1% levels.

**Table 2.1 Characteristics of Respondents**

Variable	Definition	‘Bio’ Survey <sup>a</sup>	‘Nano’ Survey <sup>b</sup>	2011 Census of Canada	Removed Respondents <sup>c</sup>
Mean					
Male <sup>d</sup>	1 if male; 0 if female	0.47	0.45	0.49	0.50
Age	Age in years	55	54	48 <sup>e</sup>	53
Education	Highest level of educational attainment: 1 if high school or less; 2 if trades certificate; 3 if college diploma; 4 if university degree; 5 if Master's degree or higher	3.46	3.43	2.31 <sup>f</sup>	3.34
Income	Annual combined household income before taxes: 1 if \$29,999 and under; 2 if \$30,000 to \$49,999; 3 if \$50,000 to \$79,999; 4 if \$80,000 to \$124,999; 5 if \$125,000 and over	3.43	3.41	2.90	3.20
BC	1 if reside in British Columbia; 0 otherwise	0.14	0.13	0.13	0.11
ON	1 if reside in Ontario; 0 otherwise	0.38	0.39	0.38	0.36
QC	1 if reside in Quebec; 0 otherwise	0.22	0.23	0.24	0.30
Pra	1 if reside in Prairie provinces, i.e., Alberta, Manitoba, Saskatchewan; 0 otherwise	0.17	0.18	0.18	0.15
Rest	1 if reside in other Canadian provinces or territories; 0 otherwise	0.09	0.07	0.07	0.08

Notes: a. ‘Bio’ survey averages based on sample size N=697.

b. ‘Nano’ survey averages based on sample size N=710.

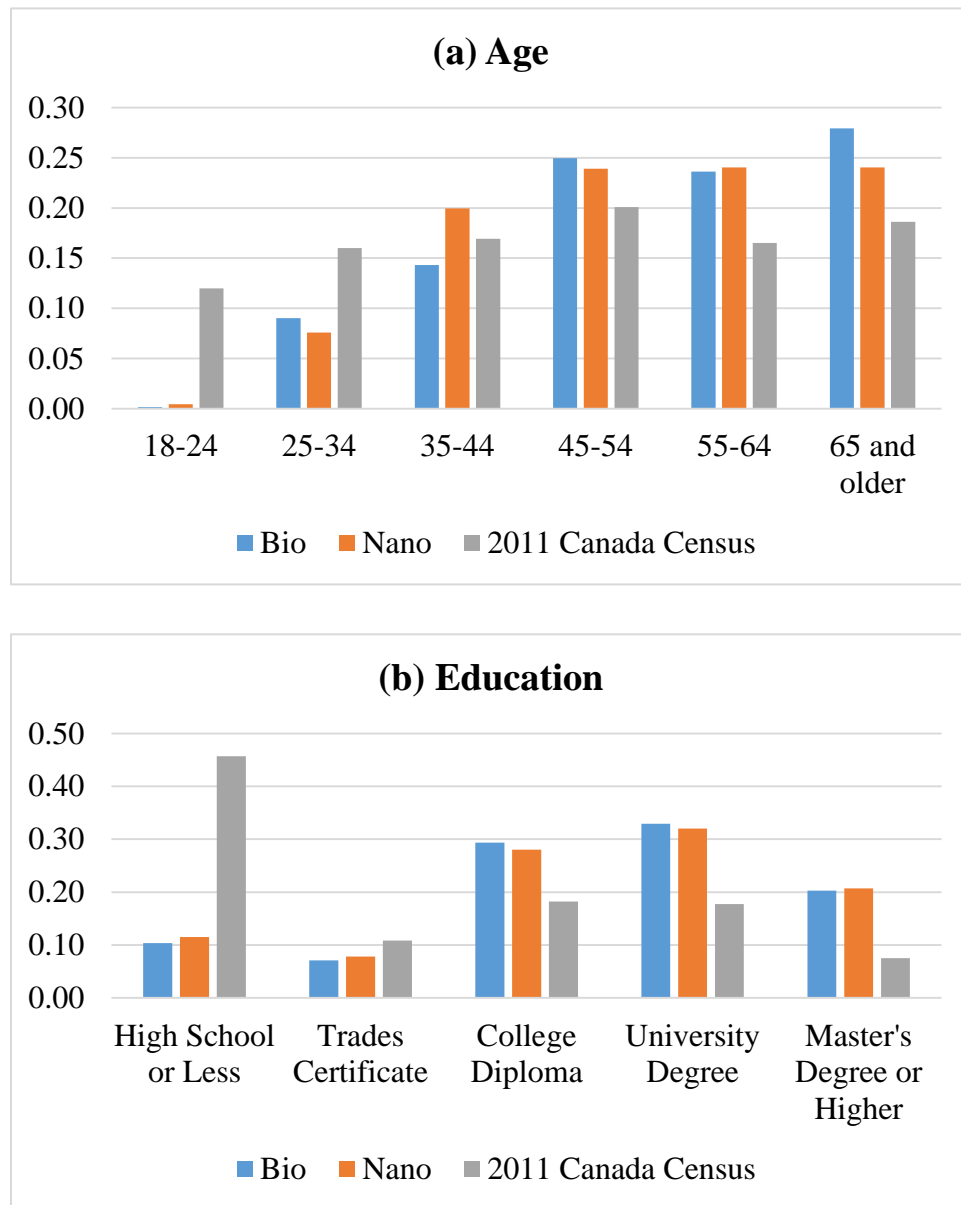
c. A total of 201 respondents were screened out from the sample, 107 removed from ‘Bio’ survey and 94 removed from ‘Nano’ survey.

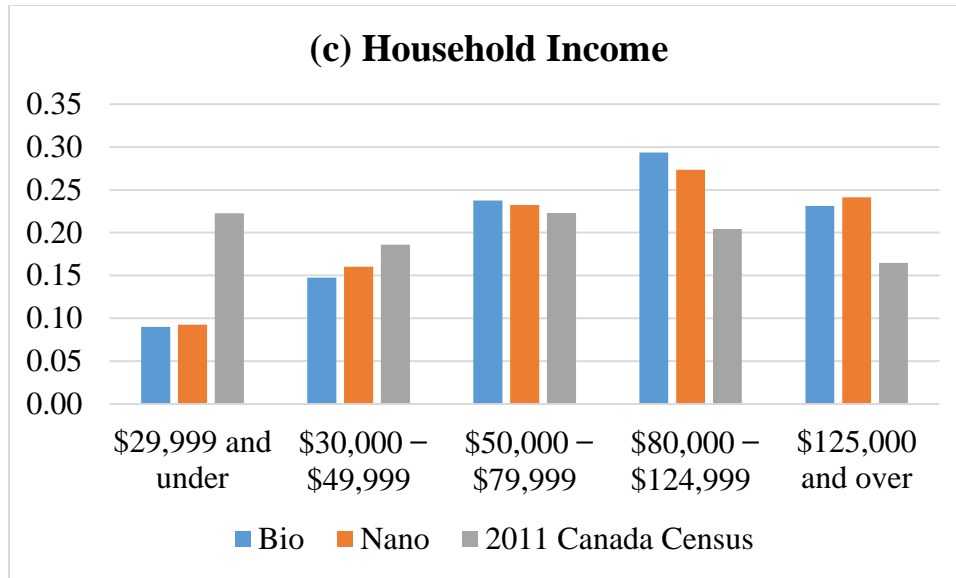
d. Respondents indicated their gender by choosing from ‘male’, ‘female’, and ‘other’ (see Appendix A or B question [GENDER]). Among all 1608 sampled respondents, only 6 chose the category ‘other’, and they have all been screened out by the sequential criteria applied earlier (although none of those criteria are related to gender). As such, only respondents choosing ‘male’ or ‘female’ were retained in the final dataset.

e. Mean age of Canadian adults only, those aged 18 or above.

f. Average education level of Canadians aged 15 years and over.

Figure 2.3 shows the sample distributions of age, education and income for the cleaned data set, and compares them with the Canadian population.





**Figure 2.3 Comparison of Socio-demographics between the Survey Sample and the Canadian Population**

As the central aim of this paper is to explore information framing effects, the following section provides a detailed description of the second main section of survey, ‘information’, by introducing the development of different information material and showing the number of respondents assigned to each information condition.

### 2.4.3 Information Conditions

The main objective of this chapter is to examine the effects of different information formats on attitudes towards novel food technologies. As such, information was deliberately developed in different formats and each respondent was randomly assigned to one of these information treatments.

As a majority (64%) of respondents reported being unfamiliar with food biotechnology (see Figure 3.4 in the next chapter), generic and neutral introductory information on biotechnology applied to agriculture and food production was provided to all respondents regardless of the information conditions to which they were assigned. In this general piece of information, biotechnology was described as a set of modern plant breeding techniques enabling scientists to work precisely with plant genes, and hence diverse plant traits could be achieved. Also, all respondents were told that scientists are using biotechnology to develop apple varieties that resist browning and are enhanced



with antioxidants (e.g., Vitamin C) (for exact wording of the introductory information, see Appendix A, question [GENERIC] and [GENERAL]).

The generic information, however, did not explain in detail which particular biotechnology was used and how these technologies work differently to achieve specific apple characteristics. Respondents assigned to the ‘no additional information (control)’ condition were furnished with only the generic introduction about biotechnology without any additional detailed information. By contrast, respondents assigned to all the other three conditions – ‘logical-scientific’, ‘narrative’, and ‘self-selection’ – were all exposed to additional information developed in distinct formats.

The additional detailed information was developed in either a logical-scientific or a narrative format, aiming to explain which particular novel food technology was used and how they differ from each other to obtain the non-browning and antioxidant-enhanced apple characteristics.

Since the first genetically modified food, the Flavr Savr slow-ripening tomato, became commercialized in 1994, the genetic modification technique has been applied in many crops to obtain desirable characteristics. Among the biotech crops that have been commercialized, most are significant commodity crops such as canola, corn, cotton and soybeans that are tolerant to herbicides or resistant to certain diseases. However, it has been widely documented that some members of the public perceive genetically modified (GM) foods as controversial and are reluctant to eat GM foods although they may know very little about this food technology (Costa-Font, Gil and Traill 2008; Hu et al. 2004; Hu, Veeman and Adamowicz 2005; Lusk et al. 2005; Health Canada 2016).

Despite growing public opposition to genetic modification, scientists did not give up improving plant genetics by developing more advanced biotech tools. It was not until the early 2010s that a ‘game-changing’ biotechnology – gene editing or known as the CRISPR-Cas9 – was developed to offer dramatic advances in the ease, precision and speed of genetic improvements. Unlike genetic modification, which is a less efficient biotech tool which generally involves inserting genes from other species into the plants at random positions to drive the desired gene expression, gene editing can precisely target at the gene location and make the desired changes within existing genes (Ledford 2015).

Compared with genetic modification, gene editing is generally regarded as a more efficient and powerful technique to alter genes. However, it is still an open question as to whether consumers differentiate between these two techniques, for example, whether people perceive them as two different plant breeding techniques and whether they assess the benefits and risks of two techniques differently. For this reason, additional detailed information about biotechnology applied in agriculture and food production was developed with a focus on describing how gene editing works differently from genetic modification.

Diverse benefits could be brought by novel food technologies, such as tolerance to harsh growing conditions and resistance to diseases or pests. This study, however, includes two novel apple characteristics that may provide tangible and direct benefits to consumers: non-browning and antioxidant-enhanced. The inclusion of the non-browning novel apple attribute is inspired by the recent approval of the Arctic Apple, which is a genetically modified apple that resists browning as it contains lower levels of enzymes that cause browning. The Arctic apple was developed by Okanagan Specialty Fruits Inc., which is an agricultural biotechnology company based in British Columbia, Canada. The non-browning trait was introduced to Arctic Apple by the RNA-interference technique (rather than the gene editing technique as hypothesized in this study), which silences the gene expression of enzymes that makes apples turn brown (Okanagan Specialty Fruits 2013).

Arctic Apple has been approved for growth and sale in both Canada and the U.S., and it is one of the first genetically modified foods marketed directly to consumers rather than farmers. Also, unlike other genetically modified products that are mainly used as food ingredients (e.g., herbicide-tolerant canola), non-browning is a more tangible attribute that consumers could directly observe. Therefore, this study examines how consumers would assess this consumer-oriented novel attribute.

In addition, as health has been rated as an important motive for food consumption (Renner et al. 2012), this study helps to understand how consumers value the healthfulness of a snackable pre-sliced apple product. Previous studies suggest that consumers are willing to pay a small premium for apples with wax coatings that are enriched with antioxidants (Markosyan, McCluskey and Wahl 2009). In this study, respondents were told that the level of health-promoting dietary antioxidants (e.g., Vitamin C) in sliced apples can be enhanced by using food technologies.

The additional detailed information, in either a logical-scientific or narrative format, was developed to introduce to respondents how novel food technologies (i.e., gene editing, genetic modification, and a commonly used food processing technique named edible coating) work differently to achieve the consumer-oriented apple characteristics (i.e., non-browning and antioxidant-enhanced).

The ‘logical-scientific’ information was developed based on factual scientific knowledge about agricultural biotechnology. The information was synthesized from resources such as peer-reviewed science journals (e.g., *Nature*), and reports available from government institutions regulating biotechnology (e.g., Health Canada and the Canadian Food Inspection Agency). The information was deliberately written in a scientific language and plain tone, purposely avoiding any metaphorical descriptions. The specific wordings and layouts adopted in the logical-scientific format thus mimic those appearing in the rigorous scientific reports (for exact wording, see Appendix A, section [Information Conditions] – Condition 2: Logical-scientific).

In addition, many studies have shown that information sources affect attitude formation (Frewer et al. 1996; Frewer, Howard and Shepherd 1998), hence the same logical-scientific information was attributed to two different sources in different versions of the logical-scientific information treatment: a government institution responsible for biotechnology regulation, ‘Health Canada’; and a community of distinguished scientists, the ‘Academy of Science | The Royal Society of Canada’. Both institutions are primary sources for disseminating scientific knowledge and facts in Canada, and their reports are mostly shown and presented in a logical-scientific format as that written for this study. Respondents were randomly assigned to the ‘logical-scientific’ condition and further randomly allocated to one of the two information sources. As such, we are able to investigate the potential effects of information sources, in addition to communication formats, on public perceptions.

The ‘narrative’ information treatment aims to provide respondents with similar information as found in the ‘logical-scientific’ condition, however, was written in a distinctly different format. The development of the narrative information condition relies on a blog article written by Emily Waltz, a science journalist specializing in writing science stories (Waltz 2015; 2017). In the blog post, she shared her experience with Arctic apples by doing a home experiment with her children. They put the Arctic apples through a set of tests, such as slicing, making apple smoothies in a

blender, and bruising apples in a backpack test by banging a backpack containing apples on the porch, and the article explains that the family found the Arctic apples outperformed conventional grocery apples in terms of being resistant to browning. On the basis of her story, I developed the narrative information, which depicts a similar set of home tests to explain how a non-browning apple would perform. In addition, I explained how gene editing and genetic modification differs in introducing a novel apple attribute using vivid language. For example, the mechanism of gene editing technique was compared to the find-and-replace function on a computer (for exact wording, see Appendix A, section [Information Conditions] – Condition 3: Narrative).

The narrative information treatment was deliberately written in a less technical language and with a vivid tone. The story-telling context and wordings adopted in the narrative format mimic those commonly seen in blog posts and news stories. Hence, the same narrative information was attributed to two different sources in two versions of the narrative information treatment: a regular consumer who reports her experience with the new apple varieties in a blog post; and a science journalist who writes for a newspaper ‘The Globe and Mail’. The narrative format represents the communication mode with which most consumers are familiar. Narratives are also the most common format journalists would use when writing science-related news articles. Respondents were randomly assigned to the ‘narrative’ condition and further randomly allocated to one of the two information sources. As such, we are able to compare the differential effects of information formats and sources on attitude formation.

The ‘logical-scientific’ and ‘narrative’ information formats differ in two main ways. First, the ‘logical-scientific’ information was written in an impersonal language with technical words, mimicking the writing style adopted by the scientific reports produced by scientists and government authorities. By contrast, the ‘narrative’ information was written in a vivid language using more metaphorical descriptions to explain the technical concepts, and this writing style resembles the communication mode used by consumers and the writing technique adopted by journalists. Second, the ‘logical-scientific’ information was written in a passive voice, by contrast, the ‘narrative’ is written in the first person with an active voice. Particularly, the first person narrator in the ‘narrative’ tells a story of concrete home experiments, while the ‘logical-scientific’ information is more abstract aiming to inform and explain the relevant subject to respondents.

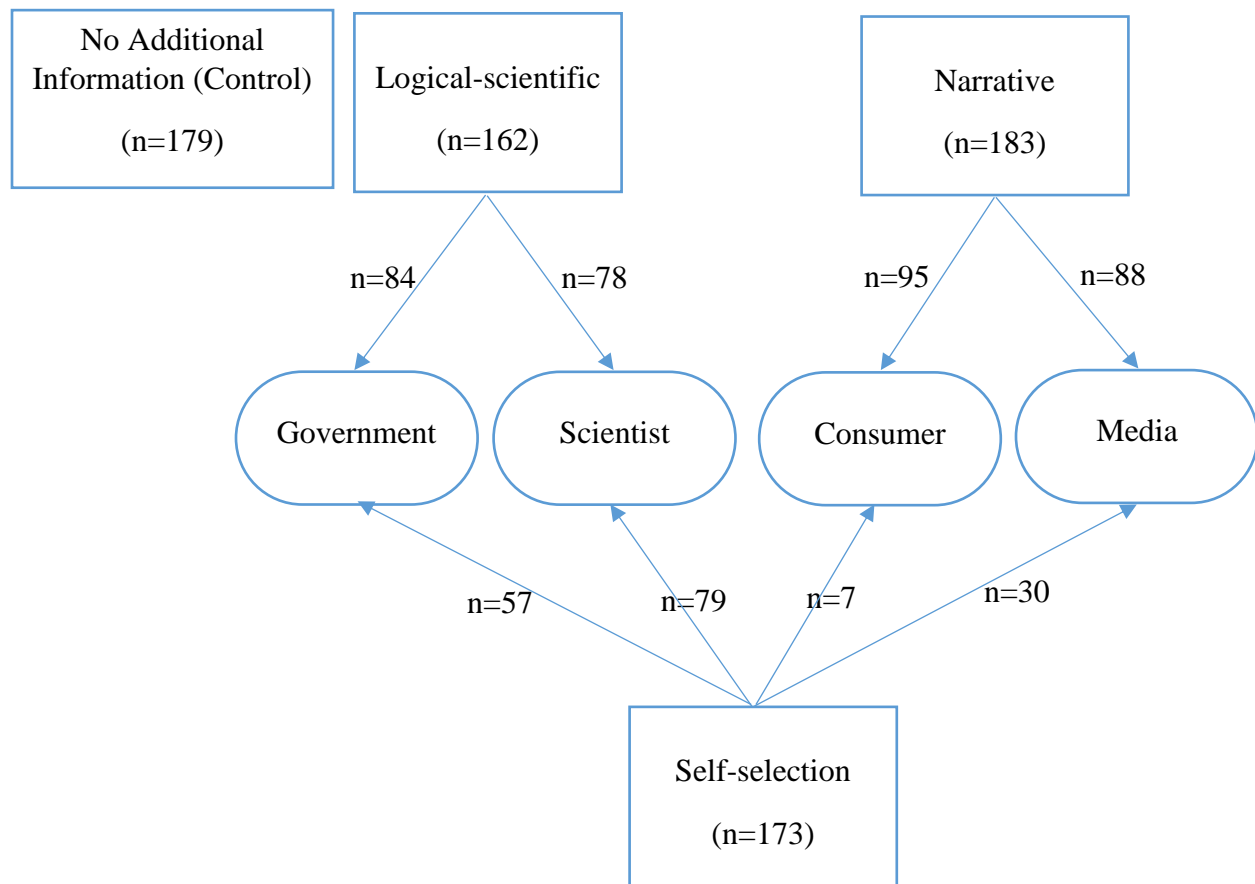
To compare the differential effects of information formats, efforts were made to ensure the same information content was conveyed in both formats, which describes each novel food technology and explains how they differ to each other in introducing novel apple characteristics. Also, a comparable length and layout of both information formats was maintained, with the ‘logical-scientific’ information containing 305 words in 5 paragraphs, while the ‘narrative’ having 370 words in 6 paragraphs (see Appendix A section [Information Conditions] for the full scripts of information developed in two formats). Both information formats were reviewed by a small pilot group who were selected to pretest the survey to check that the language, situations, and characters of messages were reasonably plausible.

Respondents assigned to the ‘logical-scientific’ and ‘narrative’ conditions were forced to read the information provided by random allocation. However, in the ‘self-selection’ condition, respondents were allowed to select one information they prefer to read from the four available options – two same-content but differently-sourced logical-scientific information treatments and two same-content but differently-sourced narrative information treatments (see Table 2.2 for the list of four options presented to respondents, or see Appendix A, section [Information Conditions] – Condition 4: Self-selection). Respondents were presented with only the titles and sources of four information options, and allowed to get access to only one information based on their choices (i.e., information content display once respondents hit the link of chosen information).

**Table 2.2 Information Options in ‘Self-Selection’ Condition**

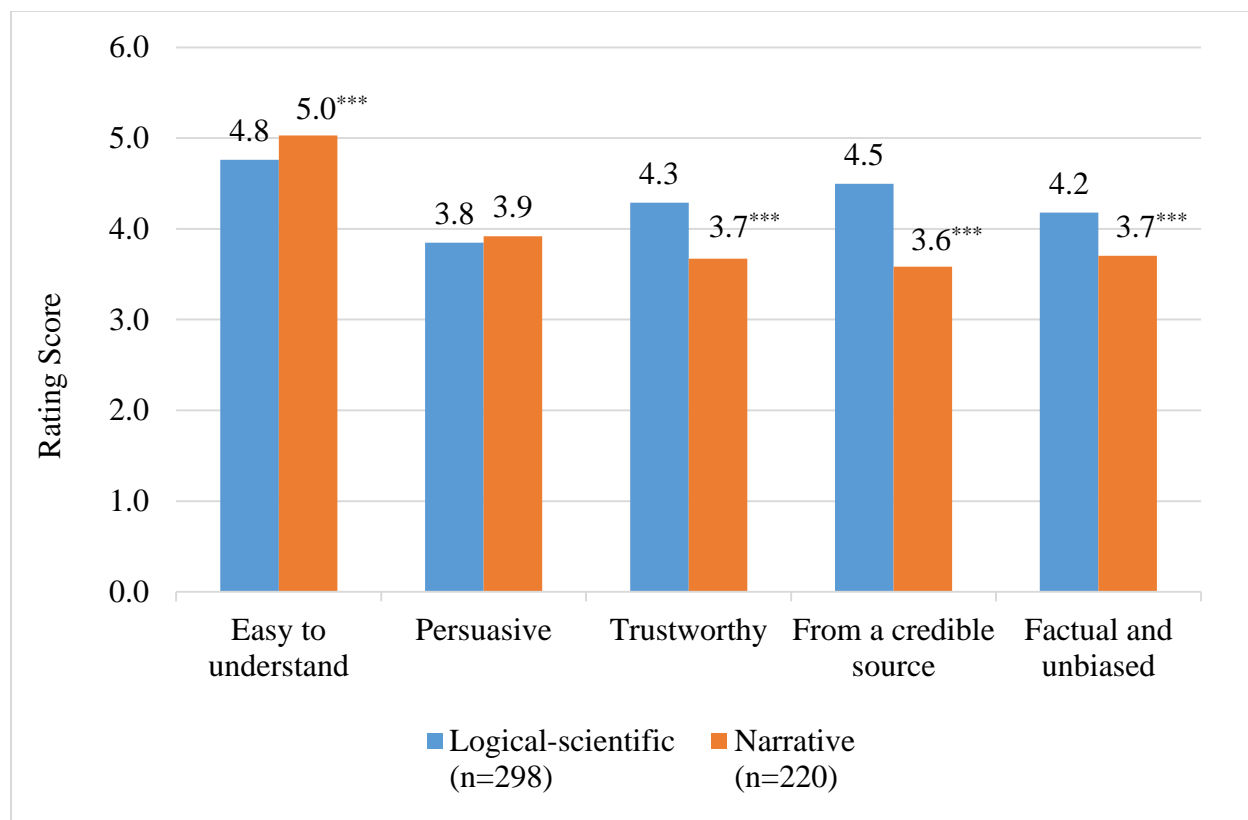
<p>Now, suppose the following information about new apple varieties becomes available to you. The titles and sources for each of these pieces of information are presented below. Please choose one of these information sources and take your time in reading the information carefully (remember you may choose only one from the four options below).</p>
<p><input type="radio"/> <b>Next Generation Biotechnology for Apple Improvements</b> <i>Health Canada</i></p> <p><input type="radio"/> <b>Biotechnology Solutions for Apple Challenges</b> <i>Academy of Science   The Royal Society of Canada</i></p> <p><input type="radio"/> <b>The Day My Family Tried Out a New Biotech Apple</b> <i>Alison Harris, consumer, Blog Post</i></p> <p><input type="radio"/> <b>Tasting and Testing a New Apple Variety – A Home Biotech Test</b> <i>Emma Cooper, science journalist, The Globe and Mail</i></p>

For each individual survey, the sample was divided into four information conditions (i.e., a between-subject design): ‘no additional information (control)’, ‘logical-scientific’, ‘narrative’, and ‘self-selection’ condition. The number of respondents assigned to each information condition and sources in the final sample set is summarized in Figure 2.4.



**Figure 2.4 Allocation of Respondents to Information Conditions**

Except for those assigned to the ‘no additional information (control)’ condition, each respondent was passively presented with or actively chose a piece of information about novel food technologies shown in either a logical-scientific or a narrative format. Immediately after reading the furnished information, respondents were asked to evaluate the quality of information by indicating to what extent the information was ‘easy to understand’, ‘persuasive’, ‘trustworthy’, ‘from a credible source’, and ‘factual and unbiased’ (1 = “not at all”, 6 = “extremely”, see Appendix A section [Information Quality Perception]). Thus, we are able to compare the perceived quality of different information formats.



**Figure 2.5 Information Quality Perception**

As shown in Figures 2.4 and 2.5, in total 298 respondents (either passively or voluntarily) read information written in the logical-scientific format, and 220 respondents read the narrative format.<sup>7</sup> Respondents' evaluations of different information formats were compared. Results indicate that respondents perceive the information written in logical-scientific format as statistically (i.e., at a 1% significance level as indicated by \*\*\*) more trustworthy, coming from more credible sources, and more factual and unbiased, compared to the information written in the narrative format. However, the narrative information outperforms the logical-scientific information in that the narratives are much easier to be understood.

To further investigate the information framing effect on consumer attitudes and choices, two sets of analyses were conducted. First, this study examines whether and how the attitudes towards novel food technologies change after respondents are exposed to information written in diverse

<sup>7</sup> Results of information quality assessment shown in Figure 2.5 are based on data pooled across information conditions and information source treatments.



formats. Second, the study examines the influence of information format on food choice behaviours. The choice experiment included in the online survey allows revealing the effects of information formats on preferences for novel food attributes and technologies. The next section 2.5 provides detail on the design of the choice experiment, and section 2.6 specifies the estimation models used for analyzing the choice data collected from choice experiment. Results of two sets of analyses are presented in section 2.7.

## **2.5 Design of the Choice Experiment**

Lancaster's (1966) characteristics approach to consumer demand theory lays a theoretical foundation for the choice experiment and choice models used in this study. Lancaster's framework decomposes products into a set of attributes. It posits that, rather than the products *per se*, the intrinsic characteristics (or attributes) of products are the direct objects of consumer choices and utilities. That is, what people desire from buying a set of products are the combination of attributes possessed in these products.

Choice experiments are a commonly used quantitative method for preference elicitation. A choice experiment allows researchers to understand how individuals value and make tradeoffs between competing attributes by asking them to identify a preferred choice over a set of hypothetical and experimentally designed alternatives. Choice experiments have been widely used in a range of consumer food studies, including eliciting consumer preferences for meat attributes (Lusk, Roosen and Fox 2003; Malone and Lusk 2017), investigating reactions to new food technologies (Erdem 2015; Hu, Adamowicz and Veeman 2006; Yue, Zhao and Kuzma 2015), and exploring preferences for food labeling information (Gao and Schroeder 2009; Hu, Veeman and Adamowicz 2005) or source of quality verification of credence attributes (Innes and Hobbs 2011).

In this study, a choice experiment was applied to explore choice behaviors related to novel food attributes and technologies, some of which are not yet available in the real market. The hypothetical choice experiment resembles a real purchasing situation more closely as it asks respondents to select the most preferred choice over all available competing options. The experiment presented respondents with descriptions of three alternatives of 500g pre-packaged apple slices with varying characteristics, based on which respondents were asked to select their preferred alternative. Respondents could also opt to buy none of the three on offer.

Sliced apples are chosen as the product examined in this study. It has been revealed that consumers perceive novel technologies differently depending on food types and benefits offered. For example, Lusk, McFadden and Rickard (2015) found that genetic engineering applied in processed foods to provide direct consumer benefits are considered as more acceptable than when applied in fresh foods such as fruits and meat. Thus, focusing on apples allows further understanding how consumers perceive novel technologies applied in fruits eaten fresh and how they react to those consumer-oriented attributes.

It is recommended to have 7 to 10 servings of fruits and vegetables a day depending on age and gender, but only 26% of Canadians meet this daily intake recommendation. Sliced apples may serve as a more appealing and convenient snack option than whole apples, encouraging healthy eating and reducing waste (Wansink et al. 2013). Thus, understanding consumer attitudes to pre-packaged sliced apple products becomes more relevant in promoting healthy snack trends.

Novel food technology has been used to develop plant varieties with desirable traits, such as tolerance to harsh growing conditions and resistance to diseases or pests. This study includes two consumer-oriented apple characteristics that can provide tangible and direct benefits to consumers: non-browning and antioxidant-enhanced. The inclusion of a non-browning apple attribute is inspired by the recent approval of the Arctic Apple, which is a genetically modified apple that resists browning as it contains a lower level of brown-causing enzymes, polyphenol oxidase (PPO). It is claimed that Arctic apples produce less than 10 percent of the PPO of their conventional counterparts (i.e., about a 90% reduction in PPO levels) (Okanagan Specialty Fruits Inc. 2017b). As a result, Arctic apples do not show superficial damage from enzymatic browning (a.k.a., primary browning) caused by fruit cutting, bruising or biting, and can stay white for at least 24 hours (Okanagan Specialty Fruits Inc. 2017c). Arctic apples, however, still show discoloration due to secondary browning which occurs when rotting/decaying starts from bacteria and fungi infections (Okanagan Specialty Fruits Inc. 2017a). The Arctic apple was developed by the Okanagan Specialty Fruits Inc., which is an agricultural biotechnology company based in British Columbia, Canada. The non-browning trait was introduced to Arctic Apple by the RNA-interference technique, which silences the gene sequence that controls the production of PPO which initiates enzymatic browning in apples.

As the Arctic Apple was approved for growth and sale in both Canada and the U.S., it is one of the first genetically modified foods marketed directly to consumers who can now ‘visually’ observe how biotechnology make changes to their food products. The non-browning attribute is expected to be a more direct and tangible for consumers than previous genetically modified commodity crops such as herbicide-tolerant, disease- and pests-resistant canola, corn, cotton, and soybeans which are mainly used as processed food ingredients and whose enhanced traits offer benefits primarily to agricultural producers.<sup>8</sup> Therefore, this study examines how consumers assess consumer-oriented apple benefits, such as non-browning and antioxidant-enhanced apple characteristics.

The selection of attributes and their levels in a choice experiment is based on the research questions that are pertinent to the study. This study aims to understand how consumers perceive and evaluate novel food traits and technologies. Since the complexity of choice tasks and the cognitive burden on respondents rises as the number of attributes and levels increase (Burton and Rigby 2012; DeShazo and Fermo 2002; Savage and Waldman 2008; Swait and Adamowicz 2001), only those closely related to the research questions are included in the choice experiment.

The apple slice alternatives in each choice set were described by four attributes: the *appearance* of the apple slices, apples can turn brown in minutes after being sliced or resist browning for a long time; *health benefit*, sliced apples are enhanced with higher levels of dietary antioxidants like Vitamin C or contain only the regular amount of antioxidants; *production method*, the aforementioned two consumer-oriented apple benefits, non-browning and antioxidant-enhanced, can be introduced through plant breeding methods (gene editing or genetic modification) or through a food processing method (edible coating). Apples produced through conventional methods will not possess any of these apple characteristics; and the retail *price* for a 500g bag of apple slices.

In a set of survey studies on food motives, visual appeal or appearance of food is not always considered by individuals as an important motive or value for their food choice; by contrast, they

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<sup>8</sup> Among the approved biotech products, very few are directly sold (in an unprocessed form) to consumers as food and they are primarily used as ingredients in processed foods. It was only recently that new biotech applications offering direct consumer benefits have been approved for human consumption, such as the non-browning Arctic apple and the bruise-resistant Innate potato.

rate nutritional or health benefit as one of the most important food motives or values (Lusk and Briggeman 2009; Renner et al. 2012). However, a number of behavioral studies have suggested that people ‘eat with their eyes’. In real food purchase or consumption situations, visual aspects of food can influence an individual’s perception, choice, and even subsequent sensory experience (e.g., the perceived tastiness) of the food (Michel et al. 2014). Also, visual and other sensory cues often trump the nutritional and health values of food (Malone and Lusk 2017). For fresh-cut apples, which potentially serve as a healthy snack option, visual appeal is of more relevance since the superficial browning or bruising can cause waste and low consumption. Thus, the choice experiment includes both appearance and health benefit attributes to examine how people make tradeoffs among these attributes introduced through novel technologies.

The novel food technologies examined in this study include two plant breeding techniques (i.e., gene editing and genetic modification) and one food processing method (i.e., edible coating). In order to assess the preferences for different food technologies, this study hypothesizes that the two new apple benefits (i.e., non-browning and antioxidant-enhanced) could be achieved by one of the three novel food technologies.

Gene editing, technically named as CRISPR-Cas9, is a new biotech tool that offers greater control, precision and speed than conventional genetic modification when making changes to plant genes. In order to introduce desired traits into a plant, genetic modification often requires inserting foreign genes from other species. The gene editing technique, however, makes smaller changes to plant genes by targeting genes that need to be edited and making necessary changes without introducing foreign genes from other organisms (Ainsworth 2015).

This study hypothesizes that apple genes responsible for the production of browning-causing enzymes are toggled off by the gene editing method, thus apples do not turn brown quickly when sliced. Similarly, enhancing the activities of apple genes responsible for the production of antioxidants through gene editing would result in apples with a higher level of antioxidants.

A commonly used processing method in the fresh-cut industry, edible coating, is also included in the choice experiment. Typically, to produce pre-packaged sliced apple products, apple slices are dipped in coating solutions containing browning inhibitors (e.g., calcium ascorbate). This study also hypothesizes that the same coating method, immersing apple slices into coating solutions containing added dietary antioxidants, would help achieve the antioxidant-enhanced characteristic.

Some studies have shown that consumers respond differently to the use of different food technologies (Colson, Huffman and Rousu 2011; Haller 2009). Thus, including three food technologies in a choice experiment allows for a better understanding of preferences for different plant breeding techniques and food processing technique.

A price attribute is typically included in a choice experiment to enable the estimation of monetary values for changes in attributes, and to provide additional realism to the decision-making scenario. The selection of price levels should be representative of retail market prices, covering the likely lowest and highest price range, as much as possible. Also, there is evidence that respondents are more sensitive to the relative rather than the absolute price levels when making choices (Kragt 2013; Hanley, Adamowicz and Wright 2005). Therefore, price levels are purposely chosen to reflect such relative increments. Based on available information (gathered from supermarkets, statistical reports, and the Internet)<sup>9</sup> about prices for sliced apple products, the three price levels selected are: Cdn\$3.69, \$4.29, and \$4.89 for a 500g bag of apple slices.

The apple attributes and their levels included in this study are summarized in Table 2.3, and an example of choice set is shown in Table 2.4. In the choice experiment, each respondent was presented with a total of 6 choice sets.

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<sup>9</sup> Price information about fresh-cut apple slices are gathered from Saskatoon-based supermarkets (e.g., Real Canadian Superstore, Walmart), websites of fresh-cut fruits processing companies (e.g., Sun Rich Fresh Foods Inc.), government's statistical reports (e.g., Consumer price indexes – average retail prices for food and other selected items by Statistics Canada: <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ155a-eng.htm>), and the Internet (e.g., Amazon.ca).

**Table 2.3 Attributes and Levels in Choice Experiment**

Attribute	Levels			
Appearance	Non-browning	Slices turn brown		
Health Benefit	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants		
Production Method	Gene editing	Genetic modification	Edible coating	Conventional
Price	\$3.69	\$4.29	\$4.89	

**Table 2.4 An Example of a Choice Set**

Imagine that you are actually buying a 500g bag of apple slices in a real grocery store. If you were able to select from the following options, which one would you buy?

	A	B	C	D
<b>Appearance</b>	Non-browning	Slices turn brown	Slices turn brown	
<b>Health Benefit</b>	Not enhanced with antioxidants	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants	I would not buy any of these products
<b>Production Method</b>	Genetic modification	Gene editing	Conventional	
<b>Price</b>	\$4.29	\$4.89	\$3.69	
<b>I would choose...</b>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A partial constant design was used in developing the choice experiment. That is, each choice set consists of two alternatives with consumer-oriented apple benefits introduced by food technology, one conventional alternative without any apple benefits, and one no-purchase option. Such a design is ‘partially constant’ in nature due to the fact that the first two alternatives are always presented with apple benefits and novel technologies, while the third alternative is the conventional option associated with no novel attribute levels.

The partial constant design imposes restrictions on the relationship among attribute levels and has an impact on the design efficiency. In the absence of novel food technology (i.e., conventional option), the appearance and health benefit attributes have to be restricted to the ‘base’ levels (i.e.,

apple slices turn brown in minutes and are not enhanced with higher levels of dietary antioxidants), and only the price levels are allowed to vary.

As the choice experiment aims at determining the influence of attributes on the choices made by respondents, the attributes included in the study and their associated levels are the primary variables of interest. The specific allocation of the attribute levels to the alternatives presented to respondents can have major impacts on the model results. Thus, rather than randomly assign attribute levels to alternatives, a deliberative experimental design allocates the attribute levels to alternatives in a systematic manner (Hensher, Rose and Greene 2015). There exist two mainstreams of experimental design: orthogonal design and efficient design.

Orthogonal designs aim to minimize the correlation between the attribute levels in the choice situations. By forcing the levels of attributes to be statistically (as opposed to behaviourally) independent, orthogonal designs would allow for an independent assessment of each attribute's contribution to the choices, as well as ensuring that parameter estimates are statistically uncorrelated to one another.

In a full factorial design, all possible attribute level combinations are included, and hence all possible effects, both main and interaction effects, can be estimated (Louviere, Hensher and Swait 2000). The size of choice situations generated in a full factorial design is determined by the number of attributes and the number of attribute levels:  $\prod_{k=1}^K L_k$ , where  $L_k$  is the number of levels associated with attribute  $k$ . In this study, there are four attributes: two described with two attribute levels, one with four levels, and one with three levels. A full factorial design would produce  $2 \times 2 \times 4 \times 3 = 48$  possible product alternatives, resulting in  $\frac{48 \times 47 \times 46}{3!} = 17,296$  possible choice situations, as each choice task contains three alternatives.

The number of choice situations produced by a full factorial design is too large and hence only a subset of choices situations can be included in one survey. There exist a number of different methods to generate a subset of choice situations while maintaining the orthogonality in attributes. A prominent method is the orthogonal fractional factorial design, which selects subsets based on the levels of higher order interaction terms. However, as opposed to the full factorial, which maintains orthogonality in all main and interaction effects, the fractional factorial retains

orthogonality in only some effects, for example, being orthogonal in main effects but correlated among interaction terms (Hensher, Rose and Greene 2015; Louviere, Hensher and Swait 2000).

Despite the fact that orthogonal designs (i.e., full factorial and orthogonal fractional factorial) are commonly applied in choice experiments, the appropriateness and value of maintaining orthogonality in attributes has recently been questioned by many scholars (Rose and Bliemer 2009). First, orthogonality is important in estimating independent effects in linear models (i.e., multicollinearity), however, discrete choice models are not linear models. In addition, orthogonality in design is often lost in the final dataset for estimation. For example, when choice situations are not equally represented in the final data, e.g., non-responses for certain choice tasks or certain blocks of choice tasks are under- or over-represented within the data due to an unequal number of respondents answering them, the data would become non-orthogonal even though the underlying design is orthogonal. Also, certain combinations of attribute levels may be dominant in a choice situation (e.g., higher quality is associated with lower price), or is implausible in reality (e.g., conventional production method introduces a non-browning characteristic into apple slices), thus they are removed from the final choice situations. By doing so, design orthogonality would not be retained in the dataset.

Given the preceding discussion, this study adopts an alternative non-orthogonal design: efficient design. Rather than merely focusing on correlations between attributes, efficient designs aim to produce more efficient data in the sense that more reliable parameter estimates (i.e., those associated with smaller predicted standard errors) can be obtained with an equal or a smaller sample size (Rose and Bliemer 2009).

An efficient design would have a ‘small’ asymptotic variance-covariance (AVC) matrix of parameter estimates, which in discrete choice models is derived by taking the inverse of the second derivatives of the log-likelihood function of the model to be estimated. As the AVC function is dependent on the design attributes and their associated levels ( $X$ ), an efficient design essentially aims to allocate attribute levels to alternatives (by manipulating  $X$ ) in a manner that can minimize the elements within the AVC matrix for the design. For example, minimizing the diagonals in an AVC matrix would lower the standard errors in the estimates (i.e., greater reliability), and hence maximize the asymptotic  $t$ -ratios for the parameter estimates at a fixed sample size.



Various measures could be used to determine the efficiency of a design, a commonly used measure is the *D-error* statistic calculated by taking the determinant of the AVC matrix,  $\Omega(X)$ , and scaling this value by the number of parameters,  $K$  (Rose and Bliemer 2009).

$$D - error = \det(\Omega(X))^{1/K} \quad (2.1)$$

By minimizing the *D-error* statistic, the elements contained within the AVC matrix are, on average, being minimized. *D-efficient* designs would be the designs that minimize the *D-error* statistic. Using SAS experimental design and choice modelling macros (Kuhfeld 2005), such as *%ChoiceEff* and *%MktBlock*, a *D-efficient* design was generated for the study. The experiments were designed as *unlabeled*, that is, the generic names of alternatives (i.e., option A, B, C, and D) have no substantive meaning to respondents.

The experimental design also accounted for the restrictions on attribute level combinations. First, choice situations containing dominant alternatives were removed from the design. For example, alternatives with the antioxidant-enhanced characteristic but lower price levels were considered as dominant over other alternatives with the same levels of attributes in non-browning and production method. Such a restriction was imposed as the antioxidant-enhanced attribute is assumed to be a trait that most people value. However, a similar restriction was not imposed on the non-browning attribute, as this study examines how respondents perceive and value, either positively or negatively, this particular attribute.

Secondly, implausible combinations of attribute levels were detected and retracted from the design. That is, novel production methods – gene editing, genetic modification, and edible coating – have to be associated with at least one of the consumer-oriented apple benefits: being non-browning, or antioxidant-enhanced, or both. Whereas, the conventional production method is not allowed to associate with any of the apple characteristics; that is, conventionally produced apple slices have to turn brown quickly and not being enhanced with antioxidants, though the price levels can vary.

Finally, as none of the apple characteristics have become available in the market yet, respondents were provided with a more familiar ‘constant’ conventional option in each choice task to closely mimic the real market situation, and to reduce the cognitive burden and likelihood of random choice behaviours among respondents. The first two alternatives (option A and B) are always

presented with some apple benefits and novel technologies, while the third alternative (option C) is always the conventional option associated with no apple benefits.

The minimum number of choice situations to generate is determined by both the number of degrees of freedom required for the design and the consideration on attribute level balance. The degrees of freedom required for a design is determined by the number of parameters to estimate, with each parameter estimate representing an additional degree of freedom. Thus, 36 choice situations should suffice for model estimation in this study. As shown in later sections, there are 6 main effects to estimate, and different numbers of interaction effects for different choice models. However, the number of parameters to estimate is unlikely to exceed this limitation.

Also, considering the attribute level balance – a desirable property of design in which each attribute level appears an equal number of times over the entire design, as such parameters can be estimated on the full range of attribute levels – 36 choice situations is enough as 36 is divisible by two, three and four.

To further reduce the number of choice tasks that respondents need to complete in the survey, these 36 choice situations were blocked into 6 sets with 6 questions in each block. Each participant was randomly assigned into a block, and answered 6 choice questions. In each choice situation, respondents were asked to choose between three alternatives or choose to buy nothing (Table 2.4). Therefore, using a web-based survey, a total of 4824 choice observations were gathered from a sample of 804 respondents. Inconsistent responses (e.g., straight-lined answers in the survey) were identified and excluded from the model estimation, resulting in a final sample of 697 respondents and 4182 choice observations used in model estimation.

## 2.6 Model Specification

Both multinomial logit (MNL) and random parameter logit (RPL) models are used to investigate the effect of information format on preference for novel food characteristics and technologies. In a random utility model (McFadden 1974), the utility that individual  $n$  receives from alternative  $j$  in choice set  $s$  is comprised of a deterministic component,  $V_{nsj}$ , and a random component  $\varepsilon_{nsj}$ .

$$U_{nsj} = V_{nsj} + \varepsilon_{nsj} = \sum_{k=1}^K \beta_k x_{nsjk} + \varepsilon_{nsj} \quad (2.2)$$

The deterministic component consists of  $K$  observed variables  $x_{nsjk}$  (i.e., those describing the alternatives' attributes, decision makers' characteristics, and decision contexts) that can influence choices, and the associated parameters  $\beta_k$  to estimate. The random component  $\varepsilon_{nsj}$  captures all unobserved effects that the analyst is unable to observe or to include into the model.

A utility-maximizing individual would choose an alternative that generates the highest utility level, thus individual  $n$  chooses alternative  $i$  in choice set  $s$  if and only if the following condition holds:

$$U_{nsi} > U_{nsj} \quad \forall j \neq i \quad (2.3)$$

Due to the presence of a random component in the utility function, we can only explain choices up to a probability level, as such the probability of individual  $n$  choosing alternative  $i$  in choice set  $s$  is:

$$P_{nsi} = Prob(\varepsilon_{nsj} - \varepsilon_{nsi} < V_{nsi} - V_{nsj}) \quad \forall j \neq i \quad (2.4)$$

In a standard multinomial logit (MNL) model, the random components,  $\varepsilon_{nsi}$  and  $\varepsilon_{nsj}$ , are assumed to be identically and independently distributed (i.i.d.) as the extreme value type 1 (EV1) distribution with mean of  $\gamma \approx 0.5772$  and variance of  $\pi^2/6$ . The probability in equation (2.4) can be analytically computed as:

$$P_{nsi} = \frac{\exp(V_{nsi})}{\sum_j \exp(V_{nsj})} = \frac{\exp(x'_{nsi}\beta)}{\sum_j \exp(x'_{nsj}\beta)} \quad (2.5)$$

$x_{nsj}$  = a vector of  $K$  observed variables influencing choices, such as alternative attributes, individual characteristics of respondents, and decision contexts,

$\beta$  = a vector of model parameters, representing the marginal utilities associated with each attribute variable.

The preference parameters are estimated by the traditional maximum likelihood procedure, which essentially maximizes the probability of observing the sequence of choices made by the sampled population. The log-likelihood function to be maximized is defined as:

$$LL(\beta) = \sum_n \sum_s \sum_i y_{nsi} \ln(P_{nsi}) \quad (2.6)$$

where  $y_{nsi}$  is an indicator function taking the value of 1 if individual  $n$  chose alternative  $i$  in choice set  $s$ , and 0 otherwise.

Due to the i.i.d. EV1 assumption on error terms, the MNL is the simplest choice model in that it is limited to capture only systematic preference variation that is associated with observed influences, to represent only proportional substitution patterns across alternatives due to the *independence from irrelevant alternatives* (IIA) property, and to model panel data only when unobserved effects are independent over time and in repeated choice situations (Train 2009).

In the choice experiment, participants are asked to make six repeated choice decisions. It is expected that, for each individual, the same unobserved factors would influence respondents' choices both across alternatives and over repeated choices situations. That is, it is unlikely that, for each respondent, his/her six sequential choices are made completely independently. Also, additional to the observed factors included in the choice model (e.g., alternative attributes, different information treatments, and other individual characteristics), choice decisions are expected to be affected by some unobserved factors that were either not collected from respondents or that we are unable to measure.

More advanced choice models have been developed to overcome the limitations of the MNL, and to accommodate both the observed and unobserved sources of choice variability. A prominent example is the random parameter model, also known as the mixed logit model, which allows for unobserved influences in modelling preferences (or tastes).

In a random parameter logit model (RPL), preference (taste) parameters are allowed to vary across individuals according to both observed and unobserved influences, such that the generic preference parameter  $\beta_k$  in equation (2.2) is re-parametrized as  $\beta_{nk}$  to reflect the individual variation in tastes.

$$U_{nsj} = V_{nsj} + \varepsilon_{nsj} = \sum_{k=1}^K \beta_{nk} x_{nsjk} + \varepsilon_{nsj} \quad (2.7)$$

Where the individual-specific preference parameters are defined as:

$$\beta_n = \beta + \Delta z_n + \Gamma v_n \quad (2.8)$$

$\beta_n$  = a vector of  $K$  individual-specific attribute parameters, representing individual  $n$ 's preferences,

$\beta$  = a vector of  $K$  population means of preference parameters which are constant over individuals,

$z_n$  = a set of  $M$  observed factors of individual  $n$  that influence the mean of taste parameters, such as different information conditions and individual characteristics,

$\Delta$  = a  $K \times M$  matrix of model parameters associated with  $z_n$ ,

$v_n$  = a vector of  $K$  random variables with zero means, known variances and zero covariances,

$\Gamma$  = a lower triangular Cholesky matrix that captures any observed heterogeneity around the variances of parameters or correlations between preference parameters.

As such, the RPL is able to capture both the observed preference heterogeneity by including  $\Delta z_n$ , and the unobserved preference heterogeneity by  $\Gamma v_n$ . The stochastic terms,  $v_n$ , are randomly distributed across respondents following a distribution pre-specified by the analyst, such as a normal, lognormal, and triangular distribution. As a result, the conditional choice probabilities and the log-likelihood functions of observing the choices made by a sampled population are both approximated by a simulation procedure as shown in the equation (2.9) and (2.10), respectively:

$$L_{nsi}(\beta_n^r) = \frac{\exp(x'_{nsi}\beta_n^r)}{\sum_j \exp(x'_{nsj}\beta_n^r)} = \frac{\exp[x'_{nsi}(\beta + \Delta z_n + \Gamma v_n^r)]}{\sum_j \exp[x'_{nsj}(\beta + \Delta z_n + \Gamma v_n^r)]} \quad (2.9)$$

$$SLL(\beta_n^r) = \sum_n l n \left[ \frac{1}{R} \sum_{r=1}^R \prod_s \prod_i L_{nsi}(\beta_n^r)^{y_{nst}} \right] \quad (2.10)$$

Where  $R$  is the total number of draws, and the  $v_n^r$  is the value of  $v_n$  in  $r$ th draw from the pre-determined distribution. By relaxing the restrictive assumption of error terms, the RPL allows us to account for both systematic and random preference heterogeneity and to deal with the dataset in a panel nature.

In this study, respondents were randomly assigned to one of the information conditions, and then were asked to make choices over alternatives with novel characteristics and produced by novel food technologies, therefore, the information treatments are expected to influence the mean of preference parameters. That is, the information condition is assumed to affect respondent  $n$ 's mean preferences for each individual novel attribute.

In the standard MNL model, effects of information format on preferences are captured via interacting the attribute variables with the information condition as shown in the equation (2.11).

$$\begin{aligned}
U_{nsj} &= \beta_{NB} \times NB_{nsj} + \beta_{AE} \times AE_{nsj} + \beta_{EC} \times EC_{nsj} + \beta_{PRI} \times PRI_{nsj} \\
&\quad + (\beta_{GE} + \gamma_{GE \times No} No_n + \gamma_{GE \times Self\_Logic} Self\_Logic_n + \gamma_{GE \times Narr} Narr_n) \times GE_{nsj} \\
&\quad + (\beta_{GM} + \gamma_{GM \times No} No_n + \gamma_{GM \times Self\_Logic} Self\_Logic_n + \gamma_{GM \times Narr} Narr_n) \times GM_{nsj} \\
&\quad + \varepsilon_{nsj}, \quad j = 1, 2, 3 \\
U_{nsj} &= \beta_j + \varepsilon_{nsj}, \quad j = 4
\end{aligned} \tag{2.11}$$

$\beta_{NB}$ ,  $\beta_{AE}$ ,  $\beta_{GE}$ ,  $\beta_{GM}$ ,  $\beta_{EC}$ , and  $\beta_{PRI}$  are the preference parameters (marginal (dis)utilities) of the attributes non-browning (*NB*), antioxidant-enhanced (*AE*), gene editing (*GE*), genetic modification (*GM*), edible coating (*EC*) and price (*PRI*).  $\beta_j$  is the alternative specific constant (ASC).  $\gamma_{GE \times No}$ ,  $\gamma_{GE \times Self\_Logic}$ ,  $\gamma_{GE \times Narr}$ ,  $\gamma_{GM \times No}$ ,  $\gamma_{GM \times Self\_Logic}$ ,  $\gamma_{GM \times Narr}$  are marginal effects of interaction terms, which capture the effects of different information formats – ‘no information’ (*No*), ‘self-select logic’ (*Self-Logic*), ‘narrative’ (*Narr*) – on the preferences for attributes *GE* and *GM*, compared to the reference ‘forced logic’ information condition (*Forced\_Logic*).  $\varepsilon_{nsj}$  is assumed to be i.i.d. EV1 with mean of  $\gamma \approx 0.5772$  and variance of  $\pi^2/6$ .

The RPL model controls for the effects of information on preference parameters by making the means of the preference parameters ( $z_n$ ) a function of information-condition-specific covariates. By doing this, we can investigate the effects of different information formats on respondents’ preferences (tastes) while allowing for unobserved preference heterogeneity. As shown in the utility function (3.11) below,

$$\begin{aligned}
U_{nsj} &= \beta_{n,NB} \times NB_{nsj} + \beta_{n,AE} \times AE_{nsj} + \beta_{n,GE} \times GE_{nsj} + \beta_{n,GM} \times GM_{nsj} + \beta_{n,EC} \times EC_{nsj} \\
&\quad + \beta_{n,PRI} \times PRI_{nsj} + \varepsilon_{nsj}, \quad j = 1, 2, 3 \\
U_{nsj} &= \beta_j + \varepsilon_{nsj}, \quad j = 4
\end{aligned} \tag{2.12}$$

the individual-specific random parameters are defined as functions of information formats,  $No_n$ ,  $Self\_Logic_n$  and  $Narr_n$ .

$$\begin{aligned}
\beta_{nk} &= \beta_k + \Delta_{k \times No} No_n + \Delta_{k \times Self\_logic} Self\_Logic_n + \Delta_{k \times Narr} Narr_n + \sigma_k v_{nk}, \quad k = GE, GM \\
\beta_{nk} &= \beta_k + \sigma_k v_{nk}, \quad k = NB, AE, EC, PRI
\end{aligned} \tag{2.13}$$

Where  $\beta_k$  is the fixed portion of mean preference for attribute  $k$ , which stays constant over individuals.  $\Delta_{k \times No} No_n$ ,  $\Delta_{k \times Self\_Logic} Self\_Logic_n$  and  $\Delta_{k \times Narr} Narr_n$  capture the observed heterogeneity around the mean of random parameters.  $v_{nk}$  is the random or unobserved component of preference, i.e., a random variable with zero mean and a known variance, thus it captures any unobserved preference heterogeneity. In this study, it is assumed that the random parameters of all non-price attributes are standard normally distributed, and the price parameter follows a constrained triangular distribution to preserve a behaviourally plausible (i.e., negative) sign over the entire sampled population.<sup>10</sup>

$$\begin{aligned} v_{nk} &\sim N[0,1] & \text{for } k = NB, AE, GE, GM, EC \\ v_{nk} &\sim triangle[-1,1] \text{ and } \sigma_k = \beta_k & \text{for } k = PRI \end{aligned} \quad (2.14)$$

Based on the preceding specifications, the simulated log-likelihood function for the RPL model is:

$$\begin{aligned} SLL(\beta_n|\Omega) &= \sum_n \ln \left[ \frac{1}{R} \sum_{r=1}^R \prod_s \prod_i L_{nsi}(\beta_n^r)^{y_{nsi}} \right] \\ L_{nsi}(\beta_n^r) &= \frac{\exp[x'_{nsi}(\beta + \Delta_{No} No_n + \Delta_{Self\_Logic} Self\_Logic_n + \Delta_{Narr} Narr_n + \sigma v_n^r)]}{\sum_j \exp[x'_{nsj}(\beta + \Delta_{No} No_n + \Delta_{Self\_Logic} Self\_Logic_n + \Delta_{Narr} Narr_n + \sigma v_n^r)]} \end{aligned} \quad (2.15)$$

## 2.7 Results and Discussion

This section presents results of two sets of analyses. Section 2.7.1 examines whether different information frames would generate differing attitudinal changes towards biotechnology. Section 2.7.2 investigates whether information and its formats have influences on food choice behaviours

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<sup>10</sup> An *a priori* assumption is that the parameter estimate for the price attribute is negative for all individuals. Several distributions allow forcing a negative sign for the price parameter, including the commonly used lognormal, exponential, and constrained (one-sided) triangular distribution, as chosen in this study. However, specifying the price parameter as a one-sided triangular distribution is more plausible as it overcomes the problematic long and thick tail of a lognormal distribution (see Hensher, Rose and Greene (2015) for a detailed discussion).

In a constrained triangular distribution,  $\beta_n = \beta + \beta v_n$ , where  $v_n \sim triangle[-1,1]$ . This specifies that the two end points of the distribution are fixed at zero and  $2\beta$ , with  $\beta$  can be positive or negative. Thus, it ensures that the entire distribution for the price parameter satisfies the one (negative) sign.

by estimating two choice models. Before presenting the results, Table 2.5 reports summary statistics of variables selected for analysis in this study under each information condition.

**Table 2.5 Definitions and Summary Statistics for Selected Variables**

Variable	Definition	Information Condition			
		None	Logical-Scientific	Narrative	Self-select
<i>Demographics</i>					
Male	1 if male; 0 if female	0.522	0.407	0.489	0.459
Age	Age in years	54.466	53.811	55.848	55.841
University	Highest level of educational attainment: 1 if obtained university degree or higher; 0 otherwise	0.508	0.497	0.503	0.622
Inc	Annual combined household income before taxes: 1 if household income was greater than \$80,000; 0 otherwise	0.506	0.520	0.483	0.596
Kid	1 if children under 18 years old live in household; 0 otherwise	0.205	0.309	0.215	0.275
<i>Attitudes prior to Information Provision</i>					
Sci	Attitudes to science and technology in general: 1 = the world is lot worse off because of science and technology; 6 = the world is lot better off because of science and technology	4.838	4.951	4.934	5.052
Sub_know	Subjective knowledge of biotechnology: 1 = know nothing at all about agricultural biotechnology; 2 = just a little; 3 = some; 4 = know a lot about agricultural biotechnology	2.218	2.265	2.251	2.289
Bio_positive	Positive prior beliefs about food biotechnology: = 1 if perceive the benefits of biotechnology outweigh its risks; 0 otherwise	0.419	0.438	0.470	0.497
Bio_negative	Negative prior beliefs about food biotechnology: = 1 if perceive the risks of biotechnology outweigh its benefits; 0 otherwise	0.391	0.340	0.284	0.312



Bio_neutral	Neutral prior beliefs about food biotechnology: = 1 if perceive the benefits and risks of biotechnology are about the same; 0 otherwise	0.190	0.222	0.246	0.191
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### ***Information Condition***

No	= 1 if randomly assigned to the ‘no additional information (control)’ condition; 0 otherwise	—
Forced_Logic	= 1 if forced to read logical-scientific information; 0 otherwise	—
Self_Logic	= 1 if voluntarily select to read logical-scientific information; 0 otherwise	—
Narr <sup>11</sup>	= 1 if forced or voluntarily select to read narrative information; 0 otherwise	—

### ***Product Attributes in Choice Experiment***

NB	Non-browning: = 1 if apple does not turn brown quickly after being sliced; 0 otherwise	—
AE	Enhanced with antioxidants like Vitamin C: = 1 if apple is enhanced with higher level of dietary antioxidants; 0 otherwise	—
GE	Gene editing: = 1 if desirable apple traits are achieved by gene editing technique; 0 otherwise	—
GM	Genetic modification: = 1 if desirable apple traits are	—

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<sup>11</sup> “Narr” condition is constructed by pooling together the responses in both “Forced\_Narr” and “Self\_Narr” conditions. I pooled narrative conditions for two reasons. First, I suspect that the number of respondents voluntarily selected narrative information (n=37) is too small to generate any statistically meaningful results. Second, this study was unable to identify any significant differences between the “Forced\_Narr” and “Self\_Narr” conditions in terms of responses of information quality assessment, changes of attitudes towards biotechnology, as well as preferences for food technologies as revealed in choice analysis. That is, the voluntary information access or self-selection of narratives has no additional impact on attitudes and behaviours, compared with narratives presented directly to respondents.

	achieved by genetic modification technique; 0 otherwise				
EC	Edible coating: = 1 if desirable apple traits are achieved by edible coating method; 0 otherwise			—	
PRI	The price levels included in choice experiment for a 500g bag of apple slices: \$3.69, \$4.29, \$4.89			—	
<i># of Obs</i>		179	162	183	173

Similar to the summary provided in Table 2.1, the age, education and income level of the sample are higher than those indicated by the 2011 Canada Census, which indicates the mean age of Canadian adults was 47.589, the percentage of population (aged 15 years and over) obtained a university degree or higher was 25.3%, and 36.9% earned a yearly household income before taxes of more than \$80,000. The sampled respondents hold relatively positive attitudes towards science and technology in general. Their (subjective) knowledge levels about agricultural biotechnology are relatively low as the respondents on average know ‘just a little’ about biotechnology. A majority of respondents hold either a positive or neutral attitude towards food biotechnology. However, there exists no significant differences in demographics and attitudes prior to information provision across the information conditions, hence it is possible to detect any effect of information formats with this between-subject design.

### 2.7.1 Attitudinal Analyses

Recall that respondents were randomly assigned to one of the four information conditions – no additional information, logical-scientific, narrative, and self-selection condition – hence each respondent was exposed (either forcedly or actively) to a piece of information about food technology written in a logic-scientific or narrative format, except for those in the control ‘no additional information’ treatment. It is shown in Figure 2.5 that the quality of different information formats was perceived as different by respondents, with logical-scientific information rated as more trustworthy, credible, and factual, while being relatively more difficult to understand than

the narrative format. This section provides more detail on how information quality was evaluated by respondents in the study.

Immediately after reading the information provided, respondents were asked to indicate to what extent the information they just read was ‘easy to understand’, ‘persuasive’, ‘trustworthy’, ‘from a credible source’, and ‘factual and unbiased’ (1 = “not at all”, 6 = “extremely”, see Appendix A section [Information Quality Perception]). Table 2.6 compares the assessment of information quality across information formats.<sup>12</sup>

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<sup>12</sup> This study was unable to identify significant impacts of information sources. That is, there was not much difference in quality assessment between sources of “government” and “scientists” for logical-scientific information, and between sources of “consumers” and “media” for narratives. As such, for each information format, data were pooled across information source treatments.

**Table 2.6 Evaluations of Information Quality across Format**

	Forced		Self-select	
	Logical-scientific (n=162)	Narrative (n=183)	Logical-scientific (n=136)	Narrative (n=37)
Easy to understand	4.60 <sup>†‡§</sup> (1.05)	4.98* (1.06)	4.95* (1.06)	5.24* (0.93)
Persuasive	3.77 (1.38)	3.91 (1.43)	3.95 (1.37)	3.97 (1.50)
Trustworthy	4.06 <sup>†‡</sup> (1.25)	3.61 <sup>*‡</sup> (1.18)	4.57 <sup>*†§</sup> (1.19)	3.97 <sup>‡</sup> (1.14)
From a credible source	4.18 <sup>†‡</sup> (1.21)	3.50 <sup>*‡</sup> (1.37)	4.88 <sup>*†§</sup> (1.03)	3.97 <sup>‡</sup> (0.93)
Factual and unbiased	3.96 <sup>‡</sup> (1.30)	3.67 <sup>‡</sup> (1.24)	4.44 <sup>*†</sup> (1.22)	3.86 (1.08)

Notes: 1. \* indicates statistically significant difference with respect to ‘forced logic’ at 5% confidence level.

2. † indicates statistically significant difference with respect to ‘forced narrative’ at 5% confidence level.

3. ‡ indicates statistically significant difference with respect to ‘self-select logic’ at 5% confidence level.

4. § indicates statistically significant difference with respect to ‘self-select narrative’ at 5% confidence level.

5. Numbers in parentheses are standard deviations.

Respondents provided with additional information about novel food technologies in the study were either forcedly exposed to different information formats (‘forced logic’ or ‘forced narrative’) or actively self-selected a preferred information in different formats (‘self-select logic’ or ‘self-select narrative’). Analyses of variance (ANOVA) were conducted to assess the perception of information quality across these four conditions. The Bonferroni procedure (Armstrong 2014) was used to conduct multiple-comparison tests across information conditions.<sup>13</sup>

<sup>13</sup> Bonferroni procedure (Armstrong 2014) is used to control for the Type I error rate. For a standard *t* test comparing means of two groups, the acceptable Type I error rate selected is  $\alpha$ , which

Results indicate that there are statistically significant differences (i.e., at a 5% confidence level) between the ‘forced logic’ and ‘forced narrative’. ‘Forced logic’ outperforms ‘forced narrative’ in terms of *trustworthiness* and *credibility of sources*. However, ‘forced narrative’ is rated as *easier to understand* than the ‘forced logic’. No statistically significant differences are found with respect to *persuasiveness* and *factualness*.

When comparing the ‘self-select logic’ and the ‘self-select narrative’, results show that ‘self-select logic’ outperforms ‘self-select narrative’ in terms of *trustworthiness* and *credibility of sources*. No statistically significant differences are found with respect to *easiness*, *persuasiveness* and *factualness*.

To detect any potential effect of ‘self-selection’, I also compare the evaluations between ‘forced logic’ and ‘self-select logic’. Results suggest that being able to actively select a logical-scientific format can induce higher perceptions of *easiness*, *trustworthiness*, *credibility of sources* and *factualness*. However, no statistically significant difference is found with respect to the *persuasiveness* of messages. I also compare ‘forced narrative’ with ‘self-select narrative’ and find that there is no statistically significant differences between the two conditions with respect to all quality measures. And a possible reason for the equality between ‘forced narrative’ and ‘self-select narrative’ is that a very small number of respondents (n=37) selected the narrative format in the self-select condition, therefore no statistically significant differences can be detected.

In summary, analysis on information quality perception supports the first hypothesis (H<sub>1</sub>) developed in section 2.3 that information shown in different formats is associated with differing quality perceptions. In particular, results indicate that respondents assess logical-scientific and narrative information provided in this study (statistically) differently. Respondents rated narrative information about biotechnology as easier to understand, while logical-scientific information as more trustworthy and credible. In addition, for the same logical-scientific information, evaluations of quality differ between whether respondents were forced to read and whether they were allowed

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is the probability of falsely rejecting the equality-of-means null hypothesis. However, when performing  $n$  separate such  $t$ -tests, the ‘overall’ probability of falsely rejecting at least one of these  $n$  hypotheses is  $1 - (1 - \alpha)^n \approx 0.26$  for  $\alpha=0.05$  and  $n=6$ . That is, the Type I error rate increases with additional number of tests. The Bonferroni procedure provides adjustment of critical values so that multiple comparison tests are performed within an acceptable Type 1 error rate.

to self-select to read the logical-scientific information, whereas no such difference was detected for the narrative format.

To examine the effects of information format on attitudes towards novel food technologies, a series of attitudinal questions were asked to respondents both before and after information provision. Before providing any detailed information about the gene editing technology (even the name of the technology, ‘gene editing’, had not yet been mentioned), respondents were asked to indicate whether they think making ‘a single precise change to a plant’s existing genes (e.g., switching on or off)’ in producing crops or foods is *natural*, *ethical*, and *safe* (1=not at all, 6=completely, see Appendix A questions [NATURE], [ETHIC] and [SAFE]). Responses to these three questions were combined to construct a single reliable index, ‘*GE\_prior*’ (Cronbach’s  $\alpha = 0.87$ ), indicating attitudes towards gene editing *before* information provision.

Then, respondents were randomly assigned to one of four information conditions, in which they were provided with detailed information about novel food technologies, such as how gene editing works differently than genetic modification to achieve the non-browning and antioxidant-enhanced apple characteristics. After reading the information and making six food choices in the choice experiment, each respondent was then asked to answer eleven questions about what they think about using gene editing technology in food production (see Appendix A questions [GE\_1] and [GE\_2]). Based on their responses, a reliable index, ‘*GE\_post*’ (Cronbach’s  $\alpha = 0.92$ ), is constructed to reflect attitudes towards gene editing *after* information provision. The change in attitude is measured by the difference between attitudes before and after information exposure, i.e.,  $GE_{diff} = GE_{post} - GE_{prior}$ .

To test the second hypothesis (H<sub>2</sub>) developed in section 2.3 that different information formats will generate differing degrees of attitudinal changes, I first investigate whether gene editing attitude prior to information provision is equal to that after the information provision. Results are summarized in Table 2.7.

**Table 2.7 Change in Attitudes towards Gene Editing across Information Format**

Information Condition	Observations	GE_prior	GE_post	GE_diff
No Information	179	3.086 (0.104) <sup>a</sup>	3.368 (0.083)	0.283 (0.074) <sup>***b</sup>
Forced Logic	162	3.062 (0.111)	3.436 (0.096)	0.374 (0.085) <sup>***</sup>
Forced Narrative	183	3.056 (0.104)	3.631 (0.085)	0.574 (0.072) <sup>***</sup>
Self-select Logic	136	3.208 (0.122)	3.602 (0.105)	0.393 (0.082) <sup>***</sup>
Self-select Narrative	37	2.730 (0.239)	3.366 (0.201)	0.636 (0.172) <sup>***</sup>

Notes: a. Numbers in parentheses are standard errors of the mean.

b. \*\*\* indicates statistically and significantly different from 0 at 1% confidence level.

The test of equality-of-means before and after information provision is a within-subject test, thus any individual-specific variables are not included (Lusk et al. 2004). Results of both parametric paired *t*-tests and non-parametric Wilcoxon signed-rank tests suggest that respondents' attitudes towards gene editing technology are statistically and significantly different (i.e., at a 1% level) before and after information provision for all information conditions. As the information pieces developed for this study are 'one-sided' statement nature, it is unsurprising to observe that attitudes towards gene editing improved after information exposure.

It also shows that, for respondents assigned to the 'no additional information' condition, their attitudes also statistically improved without being exposed to detailed information about novel food technologies. This attitude change could be a result of participating in the choice experiment, in which respondents were asked to make six food choices from a set of experimentally designed hypothetical food products varying in characteristics and production methods. Even though purposely no additional detailed information about gene editing food technology was presented during the choice experiment, to facilitate the choice tasks, respondents did receive a short instruction before entering the choice experiment, in which they were introduced to how alternative products vary in terms of appearance, health benefit, production method, and price. A 'one-sentence' description of gene editing appeared in the instruction (i.e., *gene editing: make changes to an apple's existing genes to enhance or suppress the gene's activities*) together with a description of genetic modification (i.e., *genetic modification: insert new genes from other species into apples*) (see Appendix A section [Choice Experiment]). It is possible that respondents compared the two technologies during the choice experiment, and hence responded to attitudinal questions on gene editing (i.e., GE\_post) more favourably even without being presented with additional detailed information.

A further test on the overall equality of  $GE\_diff$  values across information conditions reveals that the degree of change in attitudes towards gene editing (i.e.,  $GE\_diff$ ) statistically and significantly differs across different information conditions ( $F_{4,692} = 2.46, p < 0.05$ ). That is, different information treatments tend to induce varying changes in attitudes. To control for the effect of doing the choice experiment (i.e., accounting for the attitudinal change in ‘No Information’ condition), I use the ‘difference in differences’ test to compare the attitudinal changes across information conditions. Results suggest that narratives tend to generate greater attitudinal changes compared with the logical-scientific information.<sup>14</sup> As such,  $H_2$  is supported.

To confirm this finding, I also use a regression-based method, in which any ‘background’ effect (e.g., attitude change in ‘no information’ condition) can be controlled for. I estimated separate models for each information condition, and tested whether parameters differ across conditions. In the linear regression model, a set of exogenous variables are included to hold constant any differences in subject-specific effects across information condition.

$$GE\_post = \beta_{0,k} + \beta_{1,k}GE\_prior + \beta_{2,k}Sci + \beta_{3,k}Bio\_neutral + \beta_{4,k}Bio\_postive + \beta_{5,k}Age + \beta_{6,k}University \quad (2.16)$$

Attitude toward gene editing after information provision ( $GE\_post$ ) is expected to be influenced by the attitude toward gene editing before information exposure ( $GE\_prior$ ), the attitude on science and technology in general ( $Sci$ ), perception of risks and benefits of agricultural biotechnology ( $Bio\_neutral$ ,  $Bio\_postive$ ) and demographics ( $Age$ ,  $University$ ). The parameters for each independent variable ( $\beta_1 - \beta_6$ ), as well as the intercept ( $\beta_0$ ), are allowed to vary by information condition  $k =$  ‘no additional information’, ‘forced logic’, ‘self-select logic’, ‘narrative’.

The number of respondents who chose to view a narrative format piece of information ( $n=37$ ) is too small to obtain any statistically meaningful result, as such the ‘forced narrative’ and ‘self-select

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<sup>14</sup> Results of ‘difference in differences (DID)’ estimation indicate that the values of  $GE\_diff$  differ significantly at a 10% level when comparing between conditions of ‘Forced Narrative’ vs. ‘No Information’, ‘Forced Narrative’ vs. ‘Forced Logic’, and ‘Self-select Narrative’ vs. ‘No Information’. While  $GE\_diff$  values are not significantly different across all other conditions.



narrative' information groups are pooled together for estimation. Table 2.8 reports the estimation results.

**Table 2.8 Effect of Prior Attitude and Demographics on Post Attitude by Information**

	Format							
	No Information		Forced Logic		Self-select Logic		Narrative	
	Par.	p-value	Par.	p-value	Par.	P-value	Par.	p-value
Intercept	1.293***	0.000	0.677*	0.099	0.512	0.253	0.559*	0.051
GE_prior	0.427***	0.000	0.379***	0.000	0.496***	0.000	0.452***	0.000
Sci	0.090*	0.074	0.130**	0.049	0.237***	0.001	0.136***	0.002
Bio_neutral	0.013	0.933	0.660***	0.001	0.806***	0.000	0.491***	0.000
Bio_positive	0.708***	0.000	1.065***	0.000	0.670***	0.001	0.817***	0.000
Age	0.002	0.614	0.008	0.118	-0.004	0.487	0.011***	0.002
University	-0.183*	0.098	-0.174	0.189	-0.089	0.532	-0.169*	0.084
# of Obs.	176		158		127		214	
R <sup>2</sup>	0.606		0.588		0.650		0.652	

Notes: 1. Dependent variable is *GE\_post*.

2. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1%, respectively.

It is found that attitude toward gene editing prior to information exposure (*GE\_prior*) significantly influences the attitude after information exposure. In four information treatments, a higher (more positive) prior gene editing attitude is associated with a higher post gene editing attitude. A similar result is found for attitudes towards agricultural biotechnology in general (*Bio\_positive*). Individuals who believe the benefits of biotechnology outweigh its risks tend to react more favourably to the information on gene editing than those who believe biotechnology's risks are greater than its benefits.

In the regression, all parameters of independent variables, including the intercept, are allowed to vary by information condition. A global test is needed to test the joint hypotheses that the estimated parameters are equivalent across treatments. The likelihood ratio test rejects the null hypothesis of 'equality-of-coefficients' across information treatments ( $\chi^2_{21} = 42.65, p = 0.0035$ ), as such at least one estimated parameter differs by information condition (i.e., which could be any of the independent variable effects, the intercept term, or a combination of these)<sup>15</sup>. For example, the

<sup>15</sup> For a better test measure, I also conduct Wald tests on the equality-of-coefficients across information treatment. The chi-square value is statistically significant ( $\chi^2_{21} = 42.11, p = 0.0041$ ),

general attitude toward science and technology (*Sci*) is shown to have a statistically significant impact on gene editing attitude in the ‘self-select logic’ and ‘narrative’ condition, whereas its impact is only marginally significant in the ‘no information’ and ‘forced logic’ condition. That is, the effects of included variables differ by information treatment.

In sum, analyses on altitudinal changes support the second hypothesis ( $H_2$ ) that information communicated in different formats induce differing degrees of changes in attitudes towards gene editing technology. The detailed information developed in the study is one-sided and hence significantly improves attitudes towards gene editing technology, however, the extent to which attitude is changed varies by information format. Narratives tend to generate greater levels of changes in attitudes (positively) towards gene editing, compared with logical-scientific information format. Results from the simple linear regression also suggest that the estimated parameters differ across information treatments.

### **2.7.2 Choice Data Analyses**

In order to test the third hypothesis ( $H_3$ ) developed that information framing with respect to biotechnology will influence individuals’ choice behaviours, a choice experiment was conducted. Each respondent made six choices of pre-packaged apple slices varying in features. By observing their choices, this study examines how respondents value and make trade-offs between different novel food traits (i.e., non-browning and antioxidant-enhanced) and technologies (gene editing, genetic modification, and edible coating).

As specified in section 2.6, two sets of choice models are estimated in this study, a multinomial logit model (MNL) and a random parameter logit model (RPL) that allows for unobserved heterogeneity in preferences. Information developed for the study was displayed in distinctive formats – logical-scientific vs. narrative. It is expected that information formats will have significant impacts on respondents’ preferences for novel food technologies (i.e., gene editing and genetic modification) that were described with detailed information. Both models are estimated in

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indicating that at least one coefficient differs across groups (i.e., any of independent variables, intercept, or the both). A further Wald test on equality-of-coefficients for independent variables only (i.e., assuming effects of intercept terms are equivalent across treatment) suggests that the differences in coefficients are not just limited to differences in the intercepts ( $\chi^2_{18} = 34.22$ ,  $p < 0.05$ ), i.e., at least one coefficient of independent variables differs across information conditions.

Nlogit 6 (Econometric Software Inc). The MNL model is estimated by the maximum likelihood method, and the RPL model is estimated by maximum simulated likelihood with 200 Halton draws. Table 2.9 reports the estimation results.

**Table 2.9 Choice Model Results**

	MNL		RPL	
			<i>Random Parameters</i>	
	Coeff.	Std.Err.	Coeff.	Std.Err.
NB	0.700***	0.070	0.800***	0.180
AE	0.149**	0.065	-0.067	0.159
GE	-1.108***	0.127	-1.599***	0.302
GM	-1.616***	0.142	-2.882***	0.346
EC	-1.368***	0.097	-2.333***	0.202
PRI	-0.657***	0.038	-1.962***	0.073
			<i>Non-random Parameters</i>	
No-purchase	-3.370***	0.167	-9.754***	0.350
<b><i>Mean Shifter</i></b>				
GE: No	-0.326**	0.142	-0.856**	0.367
GE: Self_Logic	0.214	0.144	0.356	0.403
GE: Narr	0.496***	0.127	0.903***	0.341
GM: No	-0.266	0.164	-0.506	0.402
GM: Self_Logic	0.490***	0.162	1.259***	0.405
GM: Narr	0.326**	0.149	0.813**	0.372
<b><i>Standard Deviation</i></b>				
$\sigma_{NB}$			3.221***	0.178
$\sigma_{AE}$			2.684***	0.166
$\sigma_{GE}$			1.637***	0.225
$\sigma_{GM}$			1.516***	0.217
$\sigma_{EC}$			2.086***	0.218
$\sigma_{PRI}$			1.962***	0.073
<b><i>Model Characteristics</i></b>				
Log likelihood	-5348.156		-3758.611	
Pseudo R <sup>2</sup>	0.078		0.352	
AIC/n	2.564		1.806	
BIC/n	2.584		1.833	
# of Observations	4182		4182	
# of Parameters	13		19	

Notes: 1. Number of respondents = 697.

2. Number of choices observed = 4182.

3. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1%, respectively.

4. In interests of brevity, results of choice models with additional interaction effects (for instance, the socio-demographic variables) are presented in Appendix 2.I, Table 2.A1.

5. See Appendix 2.II for an analysis on the potential self-selection bias when respondents were allowed to choose from logical-scientific and narrative information formats.

According to the likelihood ratio (*LR*) test, the RPL model allowing for unobserved heterogeneity of preferences significantly improves the model fit, as indicated by the highly significant increase in the log-likelihood values ( $\chi^2(6)=16.812, p<0.01$ ). That is, the RPL model outperforms the MNL model. The statistical significance of all standard deviation estimates indicates that there is substantial unobserved preference heterogeneity with respect to all attribute parameters. That is, respondents are heterogeneous in their preferences for all attributes, including the novel apple characteristics, food technologies used to introduce apple characteristics, and price.

To understand individuals' preferences for different apple characteristics and food technologies included in the choice experiment, this study calculates the marginal utilities for each attribute. Due to the existence of interaction terms, the marginal utilities are calculated by averaging over the sampled population. For example, the marginal utility of *GE* for individual *n* is calculated as:

$$\begin{aligned}\frac{\partial U}{\partial GE} &= \beta_{GE} + \gamma_{GE \times No} No_n + \gamma_{GE \times Self\_Logic} Self\_Logic_n + \gamma_{GE \times Narr} Narr_n \\ &= -1.108 - 0.326 \times No_n + 0.214 \times Self\_Logic_n + 0.496 \times Narr_n\end{aligned}\quad (2.17)$$

The average marginal utility of *GE* is then obtained by averaging equation (2.17) over the entire sample. Table 2.10 summarizes the marginal utility estimates for MNL and RPL models.

**Table 2.10 Marginal Utilities for Individual Attributes**

	MNL		RPL	
	Mean	Std. Err.	Mean	Std. Dev. <sup>16</sup>
NB	0.700***	0.070	0.831***	3.217
AE	0.149**	0.065	-0.056	2.700
GE	-0.994***	0.093	-1.478***	1.757
GM	-1.486***	0.099	-2.522***	1.654
EC	-1.368***	0.097	-2.316***	2.074
PRI	-0.657***	0.038	-1.967***	0.803

Notes: 1. In the MNL, to compute the mean marginal utility of an attribute, the expression is computed for each observation in the sample and the average is taken.

2. In the RPL, in order to obtain the mean marginal utility, the population has to be first simulated by taking draws from the normal (for non-price attributes) or one-sided triangular (for price attribute) distributions, then compute the value of the expression for each observation and take the average.

3. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

Both models suggest that, on average, the non-browning attribute in sliced apples is welcomed by respondents, compared with apples turning brown quickly. The antioxidant-enhanced attribute is only marginally significant (at the 5% level) and positive in the MNL model, but insignificant in the RPL model. A possible reason is that apples have already been perceived by consumers as a healthy food choice as they contain high level of dietary antioxidants. As such, enhancing the level of antioxidants in apple products becomes less important and valuable to consumers.

Both models indicate that all three novel food technologies – gene editing, genetic modification and edible coating – are discounted by respondents compared to the conventional production

<sup>16</sup> In the RPL model, the mean marginal utility is computed based on equation (2.13):

$$\begin{aligned}\beta_{nk} &= \beta_k + \Delta_{k \times No} No_n + \Delta_{k \times Self\_logic} Self\_Logic_n + \Delta_{k \times Narr} Narr_n + \sigma_k v_{nk}, & k = GE, GM \\ \beta_{nk} &= \beta_k + \sigma_k v_{nk}, & k = NB, AE, EC, PRI\end{aligned}$$

The random parameters of all non-price attributes ( $v_{n,NB}$ ,  $v_{n,AE}$ ,  $v_{n,GE}$ ,  $v_{n,GM}$ ,  $v_{n,EC}$ ) are assumed to be standard normally distributed, and the price parameter ( $v_{n,PRI}$ ) follows a constrained triangular distribution. To obtain the mean marginal utility for each attribute ( $\beta_k$ ), the population has to be first simulated by taking draws from the normal (for non-price attributes) and one-sided triangular (for price attribute) distributions, then compute the value of the expression for each observation ( $\beta_{nk}$ ) and take the average. As such, standard deviations are reported for the RPL model instead of standard errors, which require a bootstrapping approach to compute.

method, *ceteris paribus*, as indicated by their significant and negative estimates in both models. In addition, among the three novel food technologies, gene editing is the least discounted, followed by edible coating method, and genetic modification is the most discounted food technology.<sup>17</sup> As expected, a higher price is associated with a lower utility level among respondents. Within this sample, respondents prefer to select from one of the three alternatives provided rather than buying nothing.

Information formats are significant in affecting preferences for novel food technologies. Recall that respondents were randomly assigned to one information condition, including ‘no additional information’ (*No*), passively or voluntarily read ‘logical-scientific’ information about biotechnology (*Forced\_Logic* or *Self\_Logic*), and passively or voluntarily read ‘narrative’ information (*Forced\_Narr* or *Self\_Narr*). These information-condition-specific covariates (*No*, *Forced\_Logic*, *Self\_Logic*, and *Narr*<sup>18</sup>) entered choice models through interaction terms (see equation (2.11) – (2.13)). For estimation purpose, I set *Forced-Logic* condition as the reference group. As such, it is possible to identify any potential effects of information exposure (by comparing *No* with *Forced-Logic*), voluntary information access (by comparing *Self\_Logic* with *Forced-Logic*) and narrative effect (by comparing *Narr* with *Forced-Logic*).

Results indicate that, *ceteris paribus*, compared to the ‘*Forced\_Logic*’ information, providing ‘*No*’ information would reduce the preference for gene editing; ‘*Narr*’ information induces higher preferences for gene editing; while the ‘*Self\_Logic*’ information is not significantly different from the ‘*Forced\_Logic*’ information in affecting preferences for gene editing. With respect to the preference for genetic modification, ‘*Narr*’ and ‘*Self\_Logic*’ information are both associated with significant and positive estimates, which indicates higher preferences for genetic modification compared to the ‘*No*’ information and ‘*Forced\_Logic*’ conditions.

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<sup>17</sup> Both models suggest that gene editing is significantly preferred than genetic modification at the 1% significance level (Wald test). Preference difference between gene editing and edible coating is also significant at the 1% level, with gene editing preferred relative to edible coating. Edible coating is found to be preferred to genetic modification, however, only at a 10% significance level.

<sup>18</sup> “*Narr*” condition is constructed by pooling together the “*Forced\_Narr*” and “*Self\_Narr*” conditions, as the number of respondents in “*Self\_Narr*” condition is too small (n=37) to identify statistically significant results. Also, I ran choice models with “*Forced\_Narr*” and “*Self\_Narr*” conditions both included, however, no significant differences in their impacts on preferences for food attributes were identified.

Results revealed slightly different information effects for gene editing and genetic modification. For both technologies, narratives help to reduce the marginal disutility of food technology compared with the forced logical-scientific information, however, voluntary information access (to logical-scientific information) was found to help reduce marginal disutility of only genetic modification. A possible reason is that consumers are more familiar with genetic modification as the technology has been applied in many crops and food products. Consumers have also been exposed to a great amount of information about genetic modification in media outlets. As such, people would value the “freedom” or “autonomy” in information choice when they are allowed to select the information they prefer to read. In contrast, gene editing technology is relatively new to consumers, therefore they have limited information access and are less familiar with it. Value of “freedom” or “autonomy” in information choice becomes less important when people have very little prior knowledge. As such, there is no significant difference between passively reading some new information or voluntarily select new information to read. This assumption (i.e., the value of voluntary information access is dependent on levels of prior knowledge or information), however, requires further research to validate.

In sum, analysis of choice data supports the third hypothesis ( $H_3$ ) that the same-content information about food biotechnology shown in different formats (logical-scientific vs. narrative) or being accessed by respondents in different manners (forced exposure or voluntary choice) can have differing impacts on preferences for novel food attributes. Results indicate that, compared with logical-scientific information, narratives could help to reduce the marginal disutility associated with food biotechnology. In addition, even when information is shown in the logical-scientific format, voluntary information access could also help to reduce the marginal disutility of food biotechnology.

## **2.8 Conclusion**

This study compares the effectiveness of logical-scientific vs. narrative information formats in communicating biotechnology to consumers. Even though a number of economic studies exist to explore information framing effect within a food context, none of them have focused on this unique information format, narratives, and examined its impacts in shaping attitudes and behaviours related to new food technologies.



To explore the effects of information format on perceptions and choice behaviours, I deliberately develop a logical-scientific and a narrative piece of information depicting the novel food traits and technologies. The logical-scientific information was written in a scientific style with a passive voice using generalized and impersonal language. In contrast, the narrative information was written in a more lively and vivid personal style. An online survey was conducted in the summer of 2016 on 804 Canadian adults. Data were collected on their perceptions of food technology and food choice behaviours. In particular, a choice experiment was included in the online survey to elicit preferences for diverse novel food attributes and technologies.

This study developed three testable hypotheses. First, it is expected that information shown in different formats is perceived by respondents as possessing different quality characteristics ( $H_1$ ). Results of attitudinal analyses indicate that the logical-scientific information is rated as more trustworthy and credible, whereas narrative information is rated as much easier to understand. It is also noteworthy that different information sources were assigned to information formats, i.e., logical-scientific information was attributed to government or scientists, while narratives were attributed to consumers or journalists. This manipulated combination of information source and format was to conform with the normative expectations (e.g., scientists are expected to use a logical-scientific language when communicating knowledge of biotechnology). Further study could violate this normative expectation by establishing source-and-format combinations that are counter-intuitive, such as letting scientists telling stories, and thus be able to examine whether such unexpected source-and-format combinations can influence quality perceptions of the information such as trustworthiness and credibility.

Second, due to the easiness to comprehend and the vivid story-like writing style, it is assumed that narrative information will induce greater attitudinal changes (positively) towards biotechnology, compared with the plain and technical logical-scientific information ( $H_2$ ). The detailed information developed in the study is one-sided and hence significantly improves attitudes towards gene editing technology, however, the extent to which attitude is changed varies by information format. Results from the simple linear regression of biotechnology attitudes also suggest that the estimated parameters differ across information treatments.

Third, it is hypothesized that information frames will have significant influence on choice behaviours related to biotechnology (H<sub>3</sub>). In order to capture consumers' choice behaviours, this study included a choice experiment, where respondents made six choices of pre-sliced apple products that vary in features such as appearance, health benefit, production method, and price. Two choice models were estimated to understand respondents' preferences for different food traits (i.e., non-browning and antioxidant-enhanced) and technologies (gene editing, genetic modification, and edible coating).

Results of both choice models, MNL and RPL, reveal that all three novel food technologies – two plant breeding techniques gene editing and genetic modification, and one food processing method edible coating – are associated with negative marginal utilities. That is, compared with the conventional production method, novel food technologies are less preferred by respondents. A closer look at the model results further indicates that respondents discount gene editing technology significantly less than genetic modification and edible coating, *ceteris paribus*. Such a finding could have significant implications for food industry and regulators. As gene editing and genetic modification are perceived and evaluated differently, informing consumers about how gene edited and genetically modified foods differ could be a key to reduce the opposition towards gene editing, which may otherwise receive similar aversion as genetic modification.

The novel food traits introduced by food technologies are shown to be welcomed by respondents. Both models suggest that the non-browning and antioxidant-enhanced attributes in pre-packaged sliced apple products are associated with significant and positive marginal utilities, even though strong evidence shows that preference heterogeneity among consumers appears to exist. Chapter 4 will unpack the nature and drivers of these preference heterogeneities by estimating latent class models (LCMs) that allow identifying different consumer segments.

Information helps to disseminate factual knowledge about food biotechnology, however, the framing or format of information matters when communicating with consumers. Analysis of choice data reveals that the same-content information about food technology shown in different formats (logical-scientific vs. narrative) or being accessed by respondents in different manners (forced exposure or voluntary choice) can have differing impacts on consumers' preferences. Compared with logical-scientific information, narratives could help to reduce the marginal

disutility associated with food biotechnology. In addition, even information shown in the logical-scientific format, voluntary information access could also help to reduce the opposition to the food biotechnology.

This study compares the effects of different information formats on new food technology perceptions and choices. Therefore, the characteristics of information developed for the study, in either logical-scientific or narrative format, will have great impacts on the identification of a potential narrative effect. The narrative message for novel food technologies used in this study is a testimonial (first-person account) by a female with children talking about her experience with novel apple characteristics and food technologies (Waltz 2015). The testimonial narrative format is used due to its simplicity: it tells a story and introduces characters but does not require the extensive exposition and development of a dramatic story (Slater et al. 2003). In addition, it is a narrative format that allows for greater control on the word choices while keeping comparable text length with the contrasting logical-scientific format.

There are several characteristics of the testimonial narrative format, however, that limit its narrative effect in this study. First, a brief testimonial narrative may be perceived as highly manipulative by readers and less trustworthy because it conveys only a single party's perspective supportive of a particular argument or a desired behaviour (Slater et al. 2003). Instead, other narrative formats, such as a conversational narrative which incorporates multiple voices and all sides/perspectives of an issue, may appear more believable and trustworthy than a one-sided account and hence can generate a greater narrative effect. For example, future studies could be more creative to develop a conversational narrative which includes multiple narrators representing different perspectives of a controversial food technology (e.g., stories told by both supporters and opponents of biotechnology).

Second, as biotechnology is perceived by the public as a controversial topic, the credibility of information provided in an experimental setting as in this study, in either logical-scientific or narrative format, can be improved by linking all the claims with some reputable peer-reviewed original scientific sources.

Third, this study is concerned only with a written text-based narrative of a new food technology, however, narrative communication can take many forms such as television documentaries and

interactive video games. A dramatized video can have greater impacts than a written narrative as the video has greater ability to transport individuals into the narrative world (Downs 2014). Thus, future studies can investigate the narrative effects of messages including audio or visual elements, such as pictures, photographs, and videos.

Fourth, this study investigates the effects of different information communication formats on novel food technology perceptions and choice. Therefore, to evaluate the information effect, the outcome variables measured are self-reported ratings to a set of attitudinal questions and choices observed in the choice experiment. Future studies may evaluate the communication formats by measuring more accurate outcome variables that reflect people's real intentions and behaviours, such as purchasing behaviours in the field over a certain time period.

Finally, information shown in both logical-scientific and narrative formats was developed by the author based on information readily available from peer-reviewed journal articles and a news story written by a science journalist. Further research could invest more time and resources in developing creative food science narratives (stories). For example, future studies may develop specific new technology information by consolidating expertise or professional skills in science writing. By doing this, researchers will have greater control over the message content, and greater capacity to create characters or situations, to build drama and suspense, and to deploy other techniques to increase the narrativity of the messages. In addition, undertaking extensive pretesting of narrative messages, e.g., characters, situation, and language use, can help to determine to what extent different information is comparable. For example, researchers can manipulate and hence match as closely as possible the logical-scientific and narrative information in their difficulty and readability levels.

Policy makers and industry participants may be interested in the findings that how a certain food technology is framed and communicated could have significant impacts on shaping consumers' attitudes and behaviours. For example, when communicating with the public about a complex policy or issue (e.g., labelling propositions or initiatives related to food biotechnology), policy makers should take into account whether the language they adopt is easily understood by the lay public and whether the frames are perceived as trustworthy and credible. Narratives that are deliberately developed with factual and unbiased scientific knowledge may be used during public communication, since they have been shown to help with promoting a greater comprehension and

engagement within the science debate (e.g., narratives are easier to comprehend than logical-scientific information) or promoting a particular outcome (e.g., help to reduce opposition to biotechnology). Also, narratives developed on the basis of unbiased scientific truth could be used to counteract the negative consequences of misinformation spread in mass or social media who is already biased towards and exploited benefits of using narratives.

Additionally, given the substantial narrative effect, both policy makers and industry participants should consider the ethical concerns of using narratives to communicate science as their impacts are difficult to counteract (Dahlstrom and Ho 2012). Results indicate that narratives attributed to less credible sources (i.e., consumer or journalist) could have stronger impacts in shaping attitudes and behaviours, compared with logical-scientific information attributed to more credible information sources (i.e., scientist or government). As such, rigorous measures have to be implemented to ensure that narratives are used in an appropriate way. For example, narratives developed by food marketers, who aim to promote their novel food products, should maintain legitimate levels of “truth” and “accuracy” in their narrative messages.

In summary, this study confirms the significance of information framing effects, and contributes to the existing economic literature by investigating the effect of a unique information format to communicate novel food technologies with consumers. This study examines whether the same scientific information presented in different formats – logical-scientific vs. narrative – yield differing attitudes and behaviours related to biotechnology. Results reveal significant information framing effect: narratives and voluntary information access both help to reduce opposition to biotechnology, compared with the plain logical-scientific information.

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## Appendix 2.I Choice Models with Additional Interaction Effects

**Table 2.A1 MNL Results with Additional Interaction Effects**

	<b>Model 1</b>		<b>Model 2</b>		<b>Model 3</b>	
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
NB	0.701***	0.070	0.586***	0.111	0.720***	0.071
AE	0.150**	0.065	0.190*	0.110	0.155**	0.067
GE	-1.119***	0.128	-1.054***	0.145	-1.671***	0.153
GM	-1.628***	0.142	-1.561***	0.159	-2.541***	0.181
EC	-1.467***	0.137	-1.372***	0.097	-1.370***	0.099
PRI	-0.657***	0.038	-0.656***	0.038	-0.683***	0.039
No-purchase	-3.372***	0.167	-3.368***	0.167	-3.480***	0.171
<b><i>Information Interactions</i></b>						
NB: No			0.033	0.138		
NB: Self_Logic			0.122	0.142		
NB: Narr			0.238*	0.127		
AE: No			0.080	0.138		
AE: Self_Logic			-0.114	0.146		
AE: Narr			-0.101	0.130		
GE: No	-0.312**	0.142	-0.389**	0.180	-0.327**	0.146
GE: Self_Logic	0.204	0.145	0.193	0.186	0.172	0.150
GE: Narr	0.520***	0.128	0.394**	0.164	0.519***	0.131
GM: No	-0.250	0.165	-0.331*	0.199	-0.329*	0.172
GM: Self_Logic	0.481***	0.163	0.469**	0.201	0.400**	0.171
GM: Narr	0.353**	0.149	0.218	0.183	0.288*	0.156
EC: No	0.153	0.147				
EC: Self_Logic	-0.087	0.165				
EC: Narr	0.229	0.142				
<b><i>Socio-demographic Interactions</i></b>						
GE: Male					0.153	0.098
GE: University					-0.163*	0.099
GE: Bio_positive					1.173***	0.099
GM: Male					0.378***	0.115
GM: University					-0.176	0.116
GM: Bio_positive					1.600***	0.121

**Table 2.A1 MNL Results with Additional Interaction Effects (Continued)**

	<b>Model 1</b>	<b>Model 2</b>	<b>Model 3</b>
<i><b>Model Characteristics</b></i>			
Log likelihood	-5345.4	-5344.9	-5142.8
Pseudo R <sup>2</sup>	0.078	0.078	0.113
AIC/n	2.564	2.565	2.486
BIC/n	2.588	2.594	2.515
# of Observations	4182	4182	4152
# of Parameters	16	19	19

Notes: 1. Number of respondents = 697.

2. Number of choices observed = 4182.

3. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1%, respectively.

Model 1 investigates if different frames of biotechnology also have impacts on participants' responses to the edible coating (*EC*) food processing method. Results reveal that, including interaction terms between the attribute variable *EC* (edible coating) and information condition variables (*No*, *Self-Logic*, *Narr*) does not improve the model fit significantly (likelihood ratio test ( $LRT$ ) =  $5.512 < \chi^2_{0.01}(3) = 11.345$ ). Also, as all these interaction terms are statistically *insignificant* in the model, it suggests that different frames of biotechnology do not have significant impacts on respondents' preferences for the edible coating technique. In fact, as shown in both information formats (Appendix A [Condition 2: Logical-scientific] and [Condition 3: Narrative]), edible coating was not discussed in details. Therefore, perceptions of edible coating are not influenced by different information frames.

Model 2 further investigates if different information frames of biotechnology have influences on respondents' preferences for the two apple characteristics – non-browning (*NB*) and antioxidant-enhanced (*AE*) – as both of them have been described as the benefits that can be achieved using biotechnology. Results indicate that, only the interaction term between *NB* and *Narr* information condition is marginally significant at the 10% significance level. That is, reading narratives may help increase the marginal utility of the non-browning apple characteristic.

In addition, the significance of information framing effects on preferences for food technology variables (*GE*, *GM*) as shown in Table 2.9 is reduced when additional interaction effects are included in Model 2. For example, in the MNL model shown in Table 2.9, narratives are found to help reduce the marginal *disutility* associated with genetic modification (i.e., significant interaction



term  $GM \times Narr$ ). By contrast, as shown in Model 2 in Table 2.A1, the impact of narratives on preferences for  $GM$  becomes *insignificant*. When comparing these two models, however, Model 2 with additional interaction effects between apple characteristics ( $NB$ ,  $AE$ ) and information conditions ( $No$ ,  $Self\_Logic$ ,  $Narr$ ) does not improve the model fit significantly ( $LRT = 6.512 < \chi^2_{0.01}(6) = 16.812$ ; Pseudo  $R^2$  unchanged; AIC/BIC increased).

By comparing Model 1, 2 in Table 2.A1 and the MNL model shown in Table 2.9, I decide to include interactions between information conditions and only two biotechnology variables ( $GE$ ,  $GM$ ) in the primary analysis reported in Table 2.9. That is, this study focuses on understanding the effects of information framing on consumers' assessments of two biotechnology methods.

In Model 3, the influence of socio-demographic characteristics on respondents' food biotechnology perceptions are examined. Overall, adding demographic variables via interaction effects improves the model fits ( $LRT = 410.712 > \chi^2_{0.01}(6) = 16.812$ ; Pseudo  $R^2$  increased; AIC/BIC decreased). Three demographic variables included are *Male* (1 if male, 0 if female), *University* (1 if obtain a university degree or higher, 0 otherwise), and *Bio\_positive* (1 if perceive the benefits of biotechnology outweigh its risks, 0 otherwise). Results indicate that, holding all else constant, males tend to be less resistant to genetic modification ( $GM$ ), compared with females; while no significant gender difference is identified for gene editing ( $GE$ ). Level of education (*University*) has no significant impact on assessment of biotechnology, however, a positive prior belief about food biotechnology (*Bio\_positive*) tends to help reduce the marginal *disutility* associated with both biotechnology methods ( $GE$  and  $GM$ ).

Individuals' socio-demographic characteristics may have significant impacts on preferences for food technologies, however, the information framing effects identified in Table 2.9 and Model 3 do not differ significantly. For example, the sign, magnitude, and significance levels of interaction terms between two technology variables ( $GE$ ,  $GM$ ) and information conditions ( $No$ ,  $Self\_Logic$ ,  $Narr$ ) are very similar in the Model 3 in Table 2.A1 and the MNL model in Table 2.9. As this study focuses on exploring the information framing effects, social-demographic influences are not included in Table 2.9 for the sake of brevity and ease of interpretation.

## Appendix 2.II An Analysis of Self-Selection Bias in Self-Selection Information Condition

To examine the differences between respondents who self-selected to read logical-scientific information (*Self\_Logic*) and those self-selected to read the narrative information (*Self\_Narr*), I compare their socio-demographic characteristics. Table 2.A2 presents the results.

**Table 2.A2 Individual Characteristics between *Self\_Logic* and *Self\_Narr* Conditions**

Variable	Definition	Information Condition		
		Self_Logic (n=136)	Self_Narr (n=37)	Self-Select (n=173)
Male	1 if male; 0 if female	0.489	0.351	0.459
Age	Age in years	55.756	56.135	55.841
University	Highest level of educational attainment: 1 if obtained university degree or higher; 0 otherwise	0.640	0.556	0.622
Inc	Annual combined household income before taxes: 1 if household income was greater than \$80,000; 0 otherwise	0.611	0.543	0.596
Kid	1 if children under 18 years old live in household; 0 otherwise	0.281	0.250	0.275
Sci	Attitudes to science and technology in general: 1 = the world is lot worse off because of science and technology; 6 = the world is lot better off because of science and technology	5.154	4.676**	5.052
Sub_know	Subjective knowledge of biotechnology: 1 = know nothing at all about agricultural biotechnology; 2 = just a little; 3 = some; 4 = know a lot about agricultural biotechnology	2.346	2.081**	2.289
Bio_positive	Positive prior beliefs about food biotechnology: = 1 if perceive the benefits of biotechnology outweigh its risks; 0 otherwise	0.507	0.459	0.497

Bio_negative	Negative prior beliefs about food biotechnology: = 1 if perceive the risks of biotechnology outweigh its benefits; 0 otherwise	0.279	0.432*	0.312
Bio_neutral	Neutral prior beliefs about food biotechnology: = 1 if perceive the benefits and risks of biotechnology are about the same; 0 otherwise	0.214	0.109	0.191

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Notes: \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1%, respectively.

Results of two-sample *t* tests suggest that the two groups of respondents are statistically but marginally (at 5% or 10% levels) different in their attitudes towards science in general (*Sci*), subjective knowledge of biotechnology (*Sub\_know*), and the percentage of respondents who believe risks of biotechnology outweighing its benefits (*Bio\_negative*). Compared to respondents who self-selected to read narrative information, those selected to read logical-scientific information are holding relatively more favourable attitudes towards science in general, self-reported as more knowledgeable about biotechnology, and fewer percentage of them (27.9%) are perceiving risks of biotechnology outweighing the benefits.

Taking these socio-demographic differences into account, I also investigate the factors that motivate respondents to self-select the logical-scientific format rather than a narrative format. Estimation results of a logistic model is presented in Table 2.A3.

**Table 2.A3 Motivating Factors for Self-Selection of Logical-scientific vs. Narrative Information**

Variable	Model Estimates	
	Par.	Std. Err.
<i>Sci</i>	0.302*	0.187
<i>Sub_know</i>	0.578**	0.285
<i>Bio_negative</i>	-0.453	0.443
<i>Trust in scientists</i>	0.051	0.277
<i>Trust in government institutions</i>	0.250	0.186
<i>Trust in science journalists</i>	-0.128	0.202
<i>Generalized trust</i>	-0.844*	0.507
<i>Intercept</i>	-1.188	1.275
<i>Log likelihood</i>	-81.606	
<i>Pseudo R<sup>2</sup></i>	0.091	
<i># of Par.</i>	7	
<i>N</i>	173	

Notes: \*, \*\*, and \*\*\* indicate parameters are significantly different from zero at the levels of 10%, 5%, and 1%, respectively.

Since there exists only two formats of information in self-selection condition – logical-scientific and narrative information, a logistic model is estimated with the dependent variable of *Self\_Logic* (1 if self-select a logical-scientific format, 0 otherwise). Factors considered to affect such format choice include respondents’ attitudes towards science in general (*Sci*), subjective knowledge of biotechnology (*Sub\_know*), whether risks of biotechnology are perceived as greater than its benefits (*Bio\_negative*), trust in different information sources (*scientists*, *government institutions*, *science journalists*), and the trust in other members of society (*generalized trust*). The institutional trust is measured by asking respondents to rate to what extent they would trust biotechnology information available from different sources (see Appendix A, question [TRUST]). The generalized trust is measured by asking respondents whether they think that most people can be trusted or that one can’t be too careful in dealing with people (see Appendix A, question [TRUST\_GEN]).

Results indicate that, *ceteris paribus*, individuals holding more favourable attitudes towards science in general and more knowledgeable about biotechnology are more likely to select a logical-scientific information in the self-selection condition. Also, individuals with higher propensity to

trust other members of society are more likely to choose a narrative format in the self-selection condition.

Although the significance levels of identified effects are only marginal (significant at 5% or 10% levels), the findings suggest the potential existence of a self-selection bias. That is, the favourable attitude to science in general and the higher level of knowledge in biotechnology may predispose individuals to select a logical-scientific format of information about biotechnology, and also dispose them to hold more favourable attitudes (or less opposition) towards the novel food technologies included in this study (i.e., gene editing, genetic modification, edible coating). As such, the significant voluntary information access effect identified in the study (reflected by the significant interactions terms  $GM \times Self\_Logic$  in Table 2.9) maybe confounded with this selection bias. In other words, due to the potential self-selection bias, the detected effect of voluntary information access on mitigating the opposition to genetic modification maybe not merely the result of voluntary information access (i.e., information treatment) but also a result of the already existing favourable food technology attitude.

Given the small size and low significance level of self-selection bias as shown in Table 2.A3, the potential confounding effect may not be of a major concern, however, it is worth further research to account for this potential confounding effect. Further research could adopt a two-step procedure to isolate the information treatment effect from self-selection bias, and thus be more confident in the voluntary information access effect identified.

## **Chapter 3 – Effects of Cultural Values on Novel Food Technology Perceptions**

### **3.1 Introduction**

As controversies about novel food technologies prevail in society, considerable effort has been made to understand consumer acceptance of novel food technologies. The ‘knowledge deficit model’ claims that ignorance is at the root of public opposition to novel technologies, and hypothesizes that support would grow as people become more informed and knowledgeable about the technologies (Allum et al. 2008; Brown 2009; Dickson 2005; Miller 1983). The public acceptance of new food technologies, however, may not grow with exposure to more scientific information, and consumers’ attitudes have rather become more persistent and polarized. For example, McFadden and Lusk (2015) find that, after receiving the same scientific information about genetically modified (GM) foods, people’s beliefs about the safety of GM foods fail to converge due to biased information assimilation (i.e., a cognitive bias that people tend to believe information which is consistent to their prior beliefs and to dismiss information contrary to prior beliefs). Similarly, Kahan et al. (2009) find that, for people holding competing cultural worldviews, their perceptions of nanotechnology polarize after being exposed to the same balanced information about nanotechnology risks and benefits. Therefore, information or knowledge is only one factor among many others that have significant impacts in shaping consumer attitudes towards novel food technologies.

The purpose of this study is to provide a more nuanced understanding of consumers’ acceptance of novel food technologies by examining the impacts of an alternative psychosocial factor – cultural worldviews. Cultural worldviews reflect people’s general attitudes towards the world and their beliefs about how the society should be organized (Finucane 2002; Kahan 2012). The theory of cultural cognition posits that individuals tend to “base their factual beliefs about the risks and benefits of a putatively dangerous activity on their cultural appraisals of these activities” (Kahan et al. 2009, p.87). In terms of food technology acceptance, people form risk and benefit perceptions of a controversial technology (e.g., GM foods) in a way that is congenial to their cultural worldviews. That is, perceptions of food technology reflect deep-rooted values or worldviews held by individuals: if the social impacts of food technology is perceived as conform to (defy) people’s cultural norms, then the technology is more (less) acceptable.

Cultural worldviews have been shown as an important factor that motivate individuals to form certain attitudes towards disputed matters, such as nanotechnology, climate change, and gun use (Kahan et al. 2007; Kahan et al. 2009; Kahan et al. 2010; Kahan, Jenkins-Smith and Braman 2011). In particular, people holding relatively hierarchical and individualistic worldviews tend to dismiss environmental and technological risks and focus on their opportunities. Hierarchists and individualists tend to believe in a natural order of society and the precedence of individual interests, however, acknowledging environmental and technological risks is perceived as threatening the competence of social elites<sup>19</sup> and the market autonomy that they support for (i.e., endangering the stratified social orders and individual interests). By contrast, individuals holding relatively egalitarian and communitarian worldviews are more likely to give credence to environmental and technological risks and focus on their threats presented to the society. Egalitarians and communitarians believe social equality and collective welfare are more important, however, environmental and technological risks are perceived as the results of commercial activities that produce social inequality and endorse unconstrained self-interest (Kahan 2012).

The theory of cultural cognition has received rising attention among scholars as a means to measure individuals' underlying values and understand the effects of values on risk perceptions. In the context of food technology acceptance, influences of cultural worldviews have also been highlighted as a promising direction for future research (Finucane and Holup 2005; Lusk, Roosen and Bieberstein 2014), however, very few empirical consumer studies have done so. As such, this study contributes to existing literature in two ways. First, as there are controversies around new food technologies (e.g., biotechnology), this study examines whether consumers' attitudes towards food technologies are an expression of their underlying worldviews. Impacts of cultural worldviews are often omitted in previous food studies, however, they could be an important factor driving consumers' disparate assessments of novel food technologies. Second, most cultural cognition studies assess cultural value effects on individuals' perceptions or attitudes, however, none of them have explored the impacts of cultural worldviews on choice behaviours. This study

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<sup>19</sup> The term 'social elites' used here is a rather broad and abstract concept that may refer to any group of people who are higher-ranked in a hierarchical social stratification. Examples of social elites are a small group of people who have a lot of advantages, power, and influences (e.g., political leaders) or a group of people who possess high intelligence, abilities and skills (e.g., scientists).

includes a choice experiment, which allows capturing choice behaviours related to novel food technologies. Significant cultural worldview effects are identified during the formation of attitudes and perceptions, however, attitudes and perceptions do not always translate into behaviours. This study provides a more nuanced understanding of cultural worldview effects by investigating their impacts using more realistic behavioural measures.

The remaining of this chapter is organized as follows. Section 3.2 reviews a set of studies on consumer acceptance of food technology and introduces the theory of cultural cognition which informs this study. Three testable hypotheses are developed and presented in section 3.3. Section 3.4 describes how data on cultural worldviews, attitudes and choice behaviours related to novel food technologies are collected from a web-based national survey. Section 3.5 specifies models used to estimate the choice data. Section 3.6 summarizes and discusses the significant cultural worldview effects identified in this study and section 3.7 concludes.

## **3.2 Literature Review**

This section begins with reviewing a sampling of studies on consumer attitudes towards novel food technologies. Then, this section introduces the theory of cultural cognition which informs this study, and provide empirical evidence of cultural value effects by summarizing previous studies that utilized cultural cognition scale. Finally, based on cultural cognition theory, a set of testable hypotheses are developed.

### **3.2.1 Consumer Attitudes towards Novel Food Technologies**

Studies have found that the public disagrees with scientists over a range of scientific topics. For example, 88% of the scientist members of the American Association for the Advancement of Science (AAAS) consider genetically modified foods as generally safe to eat, whereas only 37% of the U.S. public say the same thing (Funk and Rainie 2015). Such divergence has also been documented in other scientific topics such as the safety of vaccination (Kahan et al. 2010) and the severity of climate change (Kahan, Jenkins-Smith and Braman 2011).

Theoretical insights from psychology and behavioural economics help to understand the complexity of consumer decision-making and attitudes towards novel food technologies. Breaking away from the conventional assumption of full rationality in decision makers, studies in



psychology and behavioural economics suggest that people are boundedly rational (Simon 1955; Simon 1956; Simon 1982), and possess two systems of reasoning, one is affective, intuitive, and fast, while the other, deliberative, logical, and slow (Chaiken 1980; Epstein 1994; Evans 1984; Kahneman 2011; Petty and Cacioppo 1986; Sloman 1996; Stanovich and West 2000; Strack and Deutsch 2004). When making decisions under a high level of uncertainty and/or without sufficient knowledge, individuals tend to rely on the former system, using mental shortcuts, values, and emotions to make sense of an issue, which makes them prone to cognitive and behavioural biases (Kahneman and Tversky 1979; Kahneman 2003; McFadden and Lusk 2015; Tversky and Kahneman 1974; Tversky and Kahneman 1981). The two reasoning systems could also complement and interact with each other (Loewenstein et al. 2001). For example, a recent fMRI (brain scans) study revealed that both affective and deliberative systems were involved when people make trade-off decisions between price and the use of controversial technologies in food products (Lusk et al. 2015).

A number of empirical studies also suggest that perceptions and acceptance of novel food technologies are affected by a wide range of psychosocial factors. For example, Siegrist et al. (2007; 2008) revealed that Swiss public acceptance of and willingness-to-buy nanotechnology foods are influenced by the affection (i.e., positive or negative feelings) evoked by the new food products and social trust in the food industry. Frewer, Howard and Shepherd (1998) found that initial attitudes towards genetic engineering have significant influences on UK consumers' responses to information about genetic engineering and hence their attitudes after information provision. Roosen et al. (2015) suggested that trust in institutions, such as food industry, government agencies and consumer organizations, play an important role in German and Canadian consumers' willingness-to-pay for hypothetical orange juice produced or packaged by means of nanotechnology. Survey studies conducted in Germany and France indicated that moral variables, such as views on technological and scientific progress, as well as views on the relationship between humans and the environment, have greater impacts than religious beliefs on public perceptions of food nanotechnology (Vandermoere et al. 2010; Vandermoere et al. 2011).

Other factors that have been revealed as important in influencing public acceptance of innovative food technologies include levels of knowledge and familiarity with the technology (Bieberstein et al. 2013; Gaskell et al. 1999; House et al. 2004; McFadden and Lusk 2016), perceived naturalness

(Connor and Siegrist 2010; Rozin et al. 2004; Siegrist 2008; Siegrist, Hartmann and Sutterlin 2016; Tenbult et al. 2005), as well as socio-demographic characteristics of individuals like gender, age and educational attainment (Hallman et al. 2003; Magnusson and Hursti 2002; Moerbeek and Casimir 2005; Verdurme and Viaene 2003).

The preceding review includes only a sampling of studies that have examined consumer attitudes towards novel food technologies, of which there are many. For a more comprehensive coverage of the topic, there exist studies that systematically reviewed existing theoretical explanations and empirical evidence on consumer acceptance of innovative food technologies, such as genetic modification (Costa-Font, Gil and Traill 2008), food nanotechnology (Giles et al. 2015), and novel food technologies in general (Lusk, Roosen and Bieberstein 2014).

### **3.2.2 The Theory of Cultural Cognition**

To understand public perceptions about food technologies, an alternative factor that has often been omitted in economic literature is underlying human values or worldviews. Theoretical efforts have been made to explain societal conflict over risk, such as the cultural theory of risk perception proposed by Douglas and Wildavsky (1983) and one of its prominent variants, the theory of cultural cognition developed by Kahan (2012), which has increasingly attracted scholarly commentary.

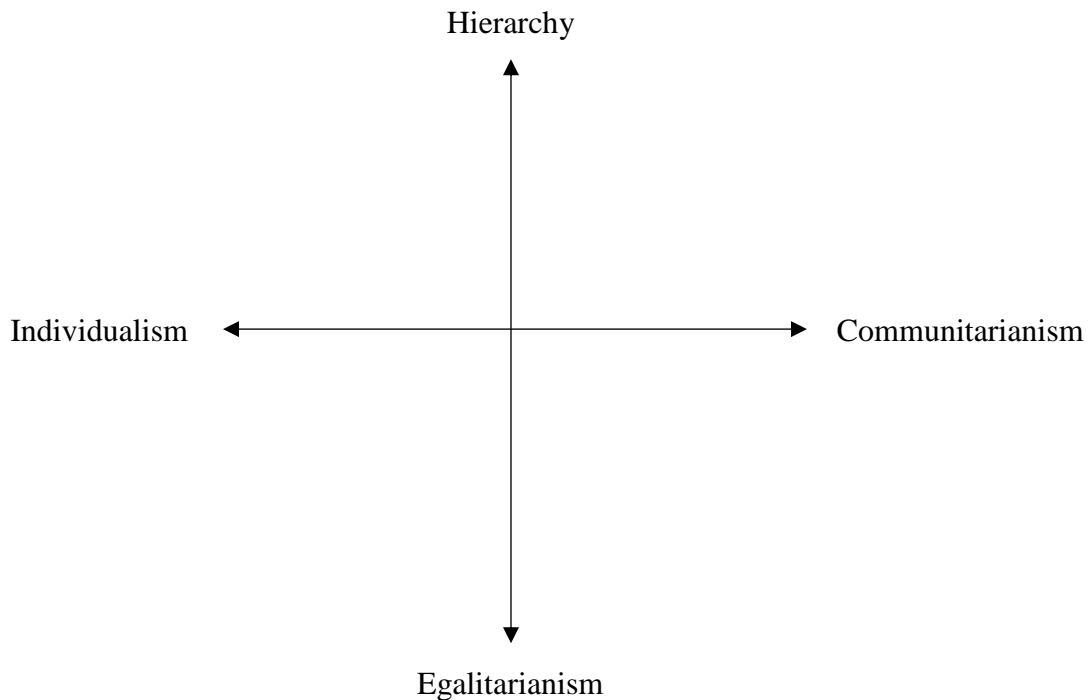
“Cultural cognition refers to the tendency of people to base their factual beliefs about the risks and benefits of a putatively dangerous activity on their cultural appraisals of these activities” (Kahan et al. 2009, p.87). Specifically, the theory of cultural cognition posits that individuals are motivated to form risk perceptions and factual beliefs about a debated matter (e.g., whether novel food technologies are safe) that are congenial to their cultural values (Kahan 2012). The influences of cultural values on attitudes are not confined to heuristic reasoning (i.e., relying on mental shortcuts, values, or emotions to make decisions), but also have impacts on the systematic reasoning (i.e., exerting efforts to process the complex information).

Cultural cognition theory provides an integration of cultural theory and the psychological mechanisms of risk perceptions. Cultural theory supplies an account of how the same psychological dynamic can generate very different risk perceptions across individuals. For example, the ‘affect heuristic’ has been revealed as a factor influencing risk perception: a more

affective feeling associated with a novel technology tends to result in greater perceived benefits but lower risks (Slovic et al. 2007). The cultural theory provides an explanation for the differences in affective feelings generated by individuals, i.e., the cultural worldviews predispose individuals to certain directions and levels of affection. In turn, psychological mechanisms furnish an account of the individual-level mechanisms through which culture shapes risk perceptions. For example, cultural worldviews can shape beliefs about risk through a psychological mechanism of ‘biased assimilation of (and search for) information’, i.e., individuals are more likely to attend to and trust the information (and source) that is consistent with their cultural values but dismiss the value-challenging messages (Kahan et al. 2009; Kahan et al. 2010).

In addition, unlike many variants of cultural theory, which measure cultural worldviews on discrete dimensions (e.g., hierarchy, egalitarianism, individualism, and fatalism), the cultural cognition theory develops its own two-dimensional cultural cognition scales that have been shown to be empirically reliable and valid. The measurements characterize individuals’ cultural worldviews along two cross-cutting dimensions: ‘hierarchy-egalitarianism’ and ‘individualism-communitarianism’. Figure 3.1 shows a visual representation of the cultural cognition scale.

Cultural cognition theory conceptualizes worldviews along two distinct continuous underlying dimensions, with each individual corresponding to one possible position in this two-dimensional cultural space. By contrast, other cultural theorists assume that the intersection of two dimensions produces four discrete worldviews which should be measured using four separate scales (Dake 1992).



**Figure 3.1 Classification of Cultural Worldviews**

Source: adapted from Fig. 28.1 in Kahan (2012)

The vertical dimension represents attitudes towards social orderings based on explicit and stable individual characteristics, such as gender, race, wealth, and so on. The *hierarchical* orientation expects these characteristics should determine the distribution of social resources and opportunities. By contrast, the *egalitarian* worldview claims these characteristics should have nothing to do with social resource distribution.

The horizontal dimension reflects attitudes towards individual interests vs. the collective social welfare, i.e., which interests should be secured and by whom. The *individualistic* orientation represents the degree to which one believes society is competitive in nature and individual interests can override social welfare, and should not be interfered by government. By contrast, the *communitarian* worldview promotes the value of solidarity, assumes that social welfare should take precedence over individual interests and any self-interest seeking behaviours are debased.

As posited by cultural cognition theory, hierarchical and individualistic individuals tend to dismiss environmental and technological risks, acknowledgement of which is perceived as threatening the

market autonomy and competence of social and governmental elites. Individuals holding relatively egalitarian and communitarian worldviews are more likely to give credence to environmental and technological risks, which are perceived as the results of commercial activities that produce social inequality and endorse unconstrained self-interest.

In empirical studies, respondents are asked to indicate their levels of agreement or disagreement on a set of cultural worldview items, which are designed to measure attitudes on equality, minority rights, gender roles, and the role government. The two scales have been found reliable and valid in a series of studies, although they have been criticized as being adhering too tightly to American political and historical background. Hence, this study uses a slightly modified version of the cultural cognition scale to capture Canadian individuals' cultural worldviews.

A set of empirical studies have been conducted to explore the role of cultural worldviews in affecting risk perceptions of diverse controversial issues, such as nanotechnology (Kahan et al. 2009), climate change (Kahan, Jenkins-Smith and Braman 2011), handgun use (Kahan et al. 2007), and vaccination (Kahan et al. 2010).

First, cultural values have been found to guide distinctive risk perception patterns across gender and racial groups. For example, the white-male effect was identified in a telephone survey study (n=1844 U.S. adults) on risk perceptions about environmental danger, handgun use, and abortion (Kahan et al. 2007). The white-male effect – a risk perception pattern that women and minorities tend to worry more about risk claims than the 'fearless' white males – is revealed as a culturally grounded identity-protective mechanism. That is, variation in cultural identities helps to explain the distinctive risk perceptions (of environmental danger, gun use, and abortion) across gender and racial groups. The hierarchical roles (e.g., protector, provider, industrial and governmental authorities, social elites) and virtues (e.g., honour and courage) are said to be largely associated with being males and whites. Hence, white males holding hierarchical and individualistic worldviews tend to be more insensitive to risks of environmental danger and handgun use, as acknowledging these risks would threaten the social roles and virtues that are essential to their cultural identities. Such selective risk perception patterns conform to individuals' cultural norms, which are shown to have stronger impacts than other individual characteristics such as political and religious affiliations.

Second, studies suggest that cultural worldviews explain how individuals expose and react to information, and why their opinions become polarized rather than converge when exposed to the same balanced information. When confronted with unfamiliar topics, such as nanotechnology, individuals tend to selectively attend to and credit the information (and information sources) in a manner that fits their cultural predispositions. The study of public perception of nanotechnology (in a non-food context) based on survey data from 1862 U.S. adults revealed this assimilated information processing pattern (Kahan et al. 2009). Results indicated that people with pro-technology cultural predispositions (i.e., relatively hierarchical and individualistic worldviews) were more likely to learn about nanotechnology prior to the study, and thus reported a higher level of familiarity with it; when they were exposed to the balanced information in the study, they were also more likely to react favourably. By contrast, people with anti-technology cultural predispositions (i.e., relatively egalitarian and communitarian) were less likely to learn about nanotechnology prior to the study, and thus reported a lower level of familiarity with it; when they were exposed to the balanced information in the study, they were also more likely to react negatively. As a result, when furnished with the same balanced information on nanotechnology, the attitude gap between people with opposing cultural worldviews widened rather than converged (Kahan et al. 2009).

Kahan et al. (2010) also found that gap in risk perceptions between people holding competing cultural worldviews grow when they are shown the same balanced arguments about risks and benefits of mandatory human-papillomavirus (HPV) vaccination. Hierarchists tend to perceive greater risks and smaller benefits of mandatory HPV vaccination, as the mandatory vaccination of school girls is seen to encourage sexual activities (girls vaccinated may falsely assume complete protection from sexual diseases and thus more likely to engage in sexual behaviours) that threaten traditional gender norms. Individualists also tend to see relatively more risks of mandatory HPV vaccination because it is seen to harm the freedom of individual decision-making. In contrast, egalitarians and communitarians tend to see greater benefits and fewer risks, because the mandatory HPV vaccination seems to express tolerance to sexual behaviours that defy traditional gender norms and reflects collective commitment to protecting all individuals. As a result, when people were exposed to the same balanced (i.e., both pro- and anti-) arguments about mandatory HPV vaccination, the risk perception gap between hierarchists and individualists on one hand, and egalitarians and communitarians on the other, grows rather than shrinks.

Third, the credibility of information sources also plays a role in information processing. Information from credible sources is perceived as to be of higher quality and more trustworthy, and hence more influential on attitude formation. The relative affinity of cultural worldviews between individuals and information sources (either persons or institutions) would determine the credibility. For example, Kahan et al. (2010) showed that the gap in risk/benefit perceptions (of HPV vaccination) between American adults with opposing cultural values *grew* if they observed arguments they were disposed to *accept* were made by advocates whose cultural values they *share*, and the arguments they were disposed to *reject* were made by advocates whose cultural values they *reject* (i.e., expected argument-advocate alignment). In contrast, the perception gap *shrank* if the argument-advocate alignment was reversed (i.e., unexpected argument-advocate alignment). Another example is given by Kahan et al. (2011) who revealed that sampled American respondents were more likely to perceive a fictional book author as a “knowledgeable and trustworthy expert” on certain topics (e.g., climate change, nuclear power, and handgun control) if the author adopted the position supporting their own cultural predispositions than they were if an author’s position contradicts their cultural predispositions.

The prominent work led by Kahan and his collaborators has successfully shown that risk perceptions are shaped by cultural values, which exert their influences through a set of psychological mechanisms. Cultural values have an important and significant role in guiding attitudes towards controversial societal issues and in explaining the persistent opinion conflicts among the public. The insights of cultural cognition have also received increased attention among other scholars and the public. For example, several Canadian scholars have applied slightly modified versions of the cultural cognition scale and shown its powerful impacts on public perceptions of a set of controversial topics such as water fluoridation (Perrella and Kiss 2015), climate change (Lachapelle, Montpetit and Gauvin 2014) and biofuels (Dragojlovic and Einsiedel 2014).

To my knowledge, however, very few economic studies have examined the impacts of cultural values in shaping attitudes and behaviours related to novel food technologies. Even consumers themselves (subjectively) rate cultural and social orientations as low in their motives for eating and selecting certain foods (Renner et al. 2012), though empirical evidence suggests the contrary. The need for a better understanding of cultural value influence in perceptions and attitudes about

novel food technologies has been increasingly recognized and has been highlighted as a promising direction for future research (Finucane and Holup 2005; Lusk, Roosen and Bieberstein 2014).

### **3.3 Study Hypotheses**

Building on the theory of cultural cognition, this paper aims to fill a knowledge gap by examining the effects of cultural values on individuals' attitudes and behaviours related to novel food technologies. The cultural values, characterized by two continuous cultural cognition scales, serve as the main explanatory factors of variances in food technology perceptions and behaviours. Based on reviewed studies, the following hypotheses are developed.

**H<sub>1</sub>:** individuals holding relatively hierarchical and/or individualistic cultural worldviews tend to hold more favourable attitudes towards novel food technology (e.g., biotechnology), compared with individuals holding egalitarian and/or communitarian worldviews.

The theory of cultural cognition posits that competing cultural values dispose individuals towards distinctive risk and benefit perceptions of disputed matters. In this study, respondents indicate their attitudes to and acceptance of agricultural biotechnology. It is expected that people holding more hierarchical and individualistic worldviews are more likely to perceive the benefits predominating the risks, and thus they are more likely to support biotechnology. By contrast, egalitarians and communitarians are more likely to perceive risks outweighing benefits, and thus more likely to take a position against biotechnology.

**H<sub>2</sub>:** individuals holding relatively hierarchical and/or individualistic cultural worldviews are more likely to purchase foods produced with novel food technology (e.g., biotechnology), compared with individuals holding egalitarian and/or communitarian worldviews.

Additional to their influences on attitude and perception formation, it is also assumed that cultural values have impacts on choice behaviours related to food technology. This study includes a choice experiment, where respondents are asked to make a series of food choices of pre-packaged apple slices that vary in features. Observing choices made by respondents helps to understand how people value and make trade-offs between novel food traits (non-browning and antioxidant-enhanced) and technologies (gene editing, genetic modification, and edible coating). More importantly, it allows examining whether underlying cultural values have impacts on individuals' preferences for these novel food attributes.



**H<sub>3</sub>:** gene editing technology, which makes changes to existing plant genes without introducing foreign genes into plants, is perceived more favourably and associated with a higher level of acceptance among consumers as compared to genetic modification.

Previous studies suggested that consumer acceptance of novel food technologies depends on particular process and format of using the technology. For example, a plant breeding method that does not involve introducing foreign genes is typically preferred than otherwise (Colson, Huffman and Rousu 2011; Hudson, Caplanova and Novak 2015). As such, it is expected that gene editing, which offers greater control, precision and speed than conventional genetic modification when making changes to plant genes, is perceived more favourably and thus is more acceptable to consumers than the genetic modification method.

The following section provides information on the collection of consumer data, which are used to test these proposed hypotheses.

### **3.4 Consumer Data**

Consumer data for this study were collected from the same online ‘Bio’ survey as introduced in Section 2.4 in chapter 2. The final ‘Bio’ dataset, used in both Chapter 2 and Chapter 3, consists of 697 respondents and 4182 choice observations. For the sake of brevity, the description of the survey design (section 2.4.1), the descriptive characteristics of the sampled respondents (section 2.4.2), and the design of the choice experiment (section 2.5) are not repeated here, as they have all been thoroughly discussed in Chapter 2. This section instead provides detailed information on the survey sections about respondents’ cultural worldviews and food biotechnology perceptions, as they are closely related to the central aim of this study.

#### **3.4.1 Cultural Worldviews**

To explore the effects of cultural values on attitudes towards novel food technologies, this survey includes a slightly modified version of the cultural cognition scales developed by Dan Kahan (referred as the ‘short form’ version in Kahan (2012)). The two scales – ‘Hierarchy-Egalitarianism (HE)’ and ‘Individualism-Communitarianism (IC)’ – consist of 12 worldview items. Each scale consists of 6 items that are balanced in worldview orientations. For example, the HE scale contains 3 items worded as supportive of the hierarchical end and 3 the egalitarian end. The IC scale has 3

items supportive of the individualistic end and the other 3 are communitarian. Respondents indicated their levels of agreement or disagreement with these statements on a six-point scale (from 1=strongly disagree to 6=strongly agree).

The six-item HE scale measures attitudes towards social stratification based on relatively stable individual characteristics such as gender and race. Examples of HE scale statements are “discrimination against minorities is still a very serious problem in our society” and “we have gone too far in pushing equal rights in this country”. The six-item IC scale measures attitudes towards individual vs. collective interests. Examples include “the government interferes far too much in our everyday lives” and “the government should do more to advance society’s goals, even if that means limiting the freedom and choices of individuals” (see Appendix A and B, section [Values] for a full list of H-E and I-C statements).

The 12 cultural worldview items load appropriately on two latent worldview dimensions (see Appendix 3.I for results of a factor analysis). All six HE items load highly on one factor, and the six IC items load strongly on a second factor, given the two underlying factors are orthogonal. Also, the internal consistency of two scales are adequately reliable: Cronbach’s  $\alpha = 0.85$  for Hierarchy-Egalitarianism (HE) scale and 0.81 for Individualism-Communitarianism (IC) scale.

Individuals’ cultural worldview scores were computed by averaging items for each scale.<sup>20</sup> A high score on the HE scale indicates that an individual holds a more hierarchical worldview, and a high score on the IC scale indicates a more individualistic orientation. These computed cultural worldview scores are used as explanatory variables in the empirical analyses presented in section 3.6.

Within the sampled population, the mean HE score is 2.63 (SD=1.19) and the mean IC score is 3.66 (SD=1.02), indicating that the sampled Canadians, on average, hold relatively egalitarian and

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<sup>20</sup> The 3 items supportive of an ‘egalitarian’ worldview orientation in HE scale and the 3 items supportive of a ‘communitarian’ worldview orientation in IC scale were reverse coded when constructing the HE and IC scores.

individualistic worldviews.<sup>21</sup> Figure 3.2 provides a graphical representation of cultural worldviews held by sampled Canadians.

To facilitate analysis, respondents were also assigned to different cultural groups. Respondents were classified as either ‘Hierarchists’ or ‘Egalitarians’, and as either ‘Individualists’ or ‘Communitarians’, depending on their cultural scores relative to the sample medians of each scale. For example, a respondent with a HE score greater than the sample median of the HE scale, would be designated as a ‘Hierarchist’, otherwise an ‘Egalitarian’. A respondent with IC score higher than the sample median of IC scale, would be designated as an ‘Individualist’, otherwise a ‘Communitarian’.



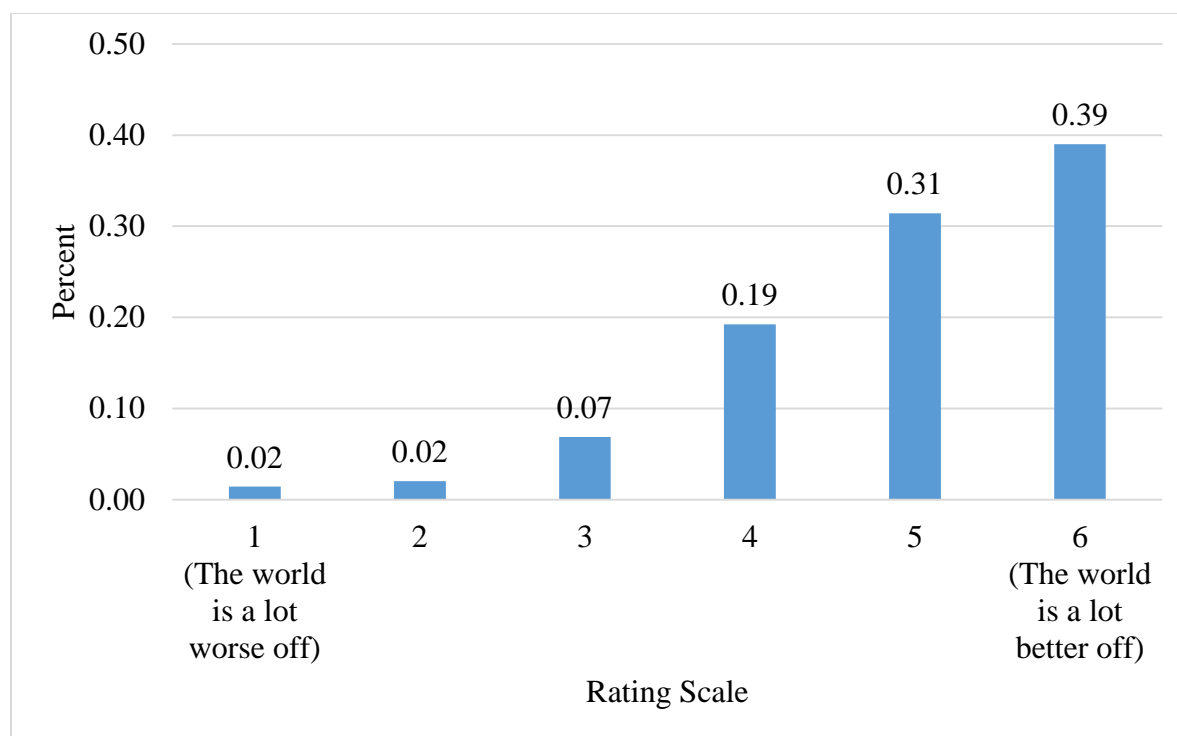
**Figure 3.2 Graphical Representation of Sampled Population’s Cultural Worldviews**

<sup>21</sup> To examine whether difference in cultural worldviews exists between respondents residing in Quebec and the rest of Canada, see Appendix 3.II.

### **3.4.2 Food Technology Perceptions and Attitudes**

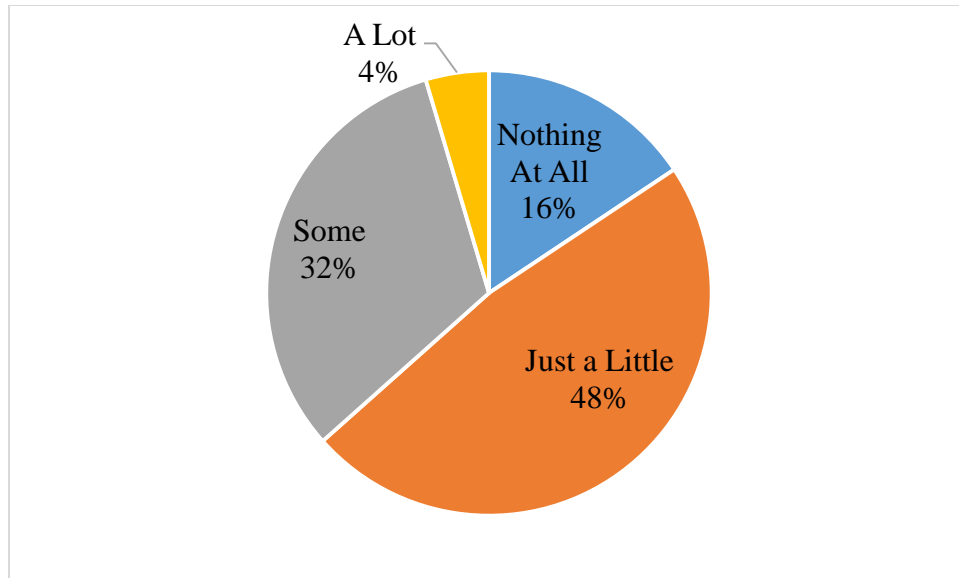
Data on attitudes towards food technologies are collected from the online survey. This section summarizes findings on sampled Canadians' knowledge, risk/benefit perceptions and acceptance of agricultural biotechnology.

Before providing respondents with any detailed information on food technologies, their attitudes towards science and technology in general are measured by asking if they consider 'the world is a lot worse off (1)' or 'the world is a lot better off (6)' because of science and technology (Appendix A question [GNR]). This question is taken from the expert panel report given by Council of Canadian Academies (2014), who presented a comprehensive examination of Canada's science culture by assessing Canadians' science attitudes, engagement, and knowledge. As the report shows, Canadians have positive attitudes towards science and technology with approximately three-quarters of Canadians agreeing with statements that 'all things considered, the world is better off because of science and technology'. The sample reveals a similar result that a vast majority of sampled Canadians viewed scientific and technological advances positively (see Figure 3.3 for the distribution of responses to this question). In the multivariate regression analysis (section 3.6.1), responses to this question are used as an explanatory variable (*Sci*) for attitudes towards biotechnology.



**Figure 3.3 Distribution of Views on Science and Technology in General**

Respondents' knowledge of biotechnology was also solicited. All respondents responded to a self-reported, subjective knowledge question used in previous studies (Cobb and Macoubrie 2004; Kahan et al. 2009). Respondents indicated how much they knew about agricultural biotechnology before the study (from 1=nothing at all to 4=a lot) (Appendix A question [KNOW]). A majority of respondents in the sample (64%) reported being relatively unfamiliar with biotechnology, knowing nothing at all or just a little (see Figure 3.4). Despite using different self-reported, subjective knowledge scales, other studies also suggested low levels of knowledge about biotechnology among Canadians (Health Canada 2016), U.S. (McFadden and Lusk 2016) and European consumers (House et al. 2004).



**Figure 3.4 Familiarity with Agricultural Biotechnology**

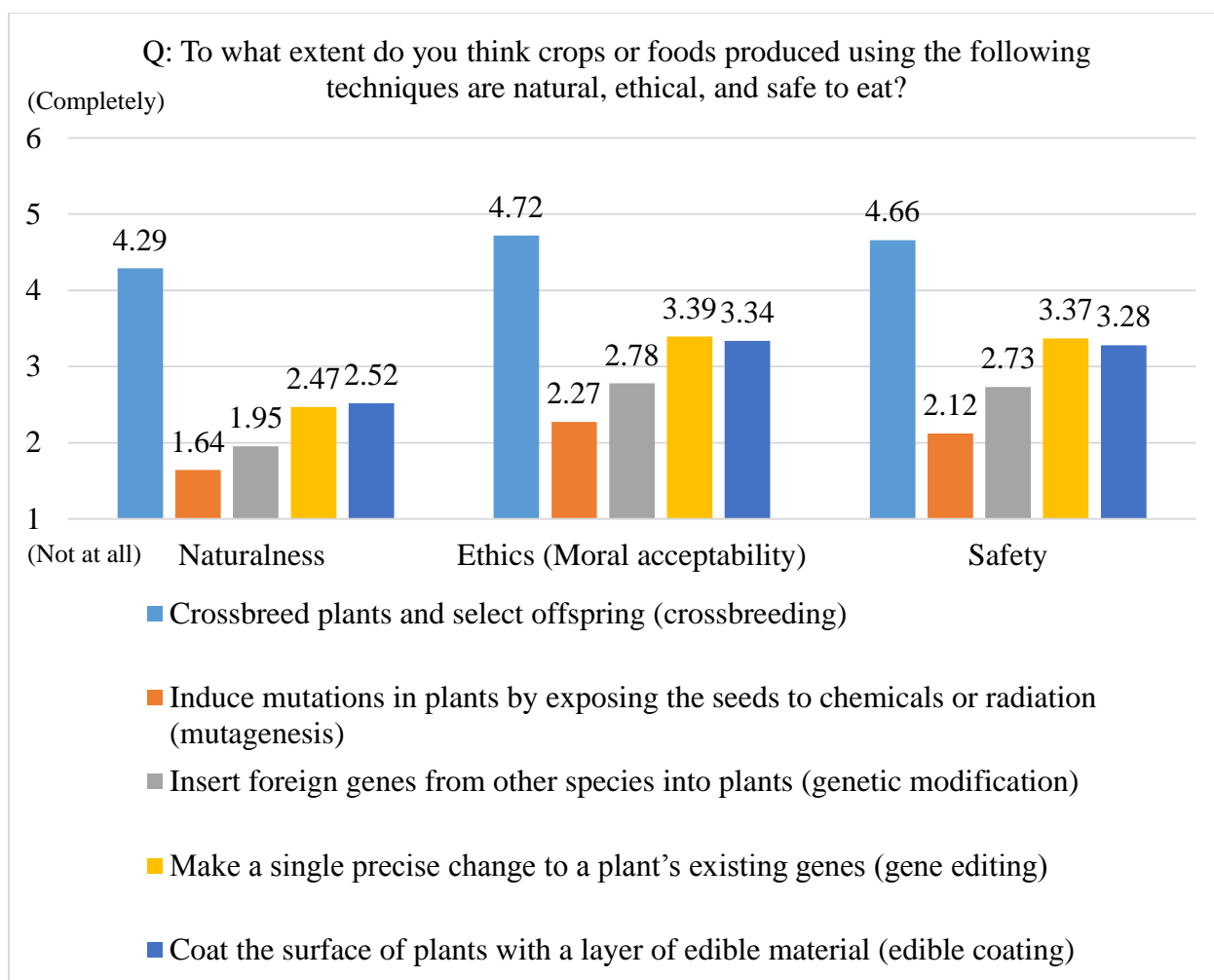
Respondents' perceptions about benefits and risks of agricultural biotechnology were solicited. All respondents indicated whether they believed 'the risks of food biotechnology will greatly outweigh its benefits (1)', 'the risks of food biotechnology will slightly outweigh its benefits (2)', 'the benefits and risks of food biotechnology are about the same (3)', 'the benefits of food biotechnology will slightly outweigh its risks (4)', or 'the benefits of food biotechnology will greatly outweigh its risks (5)' (Appendix A question [RISK]). This perception question is adapted from the study by Kahan et al. (2009) who examined the role of cultural values in affecting perceived risks and benefits of nanotechnology. As shown in Table 3.1, 33.14% of sampled Canadians believed the risks of biotechnology outweigh benefits. 45.63% of respondents perceived the benefits of biotechnology predominated its risks, and the remaining 21.23% of respondents believed the benefits and risks are equal or were uncertain about the technology. The sample suggests that there are more consumers holding positive beliefs about biotechnology than those holding negative beliefs, however, other studies on Canadian consumers revealed different results. For example, Veeman, Adamowicz and Hu (2005) found that only 37% of sampled Canadians (n=882) agreed with the statement that 'all things considered, benefits of genetic engineering in food production outweigh risks', whereas, more respondents (43%) disagreed, and the remaining 20% are indifferent. Results of another study by Strategic Counsel (2016) indicated that nearly half (48%) of sampled Canadians (n=2018) are holding neutral impressions of food biotechnology,

30% negative, and the remaining 22% positive. In the multivariate regression analysis (section 3.6.1), respondents' risk perceptions of biotechnology are used as covariates (*Risk*) in explaining biotechnology attitude formation.

**Table 3.1 Risk and Benefit Perceptions of Agricultural Biotechnology**

Risks greatly outweigh benefits	14.92%
Risks slightly outweigh benefits	18.22%
Benefits and risks are about the same	21.23%
Benefits slightly outweigh risks	24.68%
Benefits greatly outweigh risks	20.95%

Before information provision, this survey also solicited evaluations of five food technologies – crossbreeding, mutagenesis, genetic modification, gene editing, and edible coating – based on how strongly respondents perceived these technologies were natural, ethical, and safe (1=not at all, 6=completely) (Appendix A question [NATURE], [ETHIC], [SAFE]). Figure 3.5 shows a visual comparison of these perceptions.



**Figure 3.5 Perceptions of Naturalness, Ethics, and Safety**

Among the five food production methods, crossbreeding was perceived as being the most natural, ethical and safe method; while mutagenesis by chemicals or radiations were perceived as the least natural, ethical and safe production method. When comparing the two biotechnologies, genetic modification which often involves introducing foreign genes into plants vs. the newer gene editing technique which makes changes to plants' existing genes only, it is found that respondents perceived the two methods (statistically and significantly) differently. Gene editing was perceived as being more natural, ethical, and safer than genetic modification ( $H_3$  is supported). Such perception patterns may have large implications on the future market introduction of gene edited crops and related regulatory measures, as consumers may perceive the two techniques differently once they have better knowledge about the distinction between the two methods.

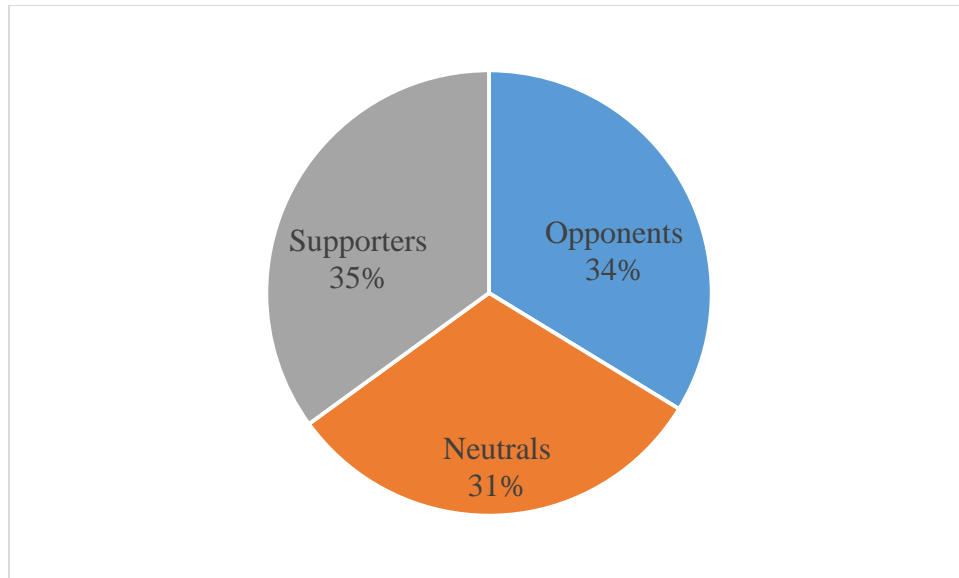


Results show that mutagenesis, which was described in the survey as a process that induce mutations by chemicals and radiation exposure, was perceived more negatively than the two biotechnologies. However, the reverse pattern is often observed in a real market. Even though genetic modification can offer a much higher level of precision, speed, and control in altering plants' genes than mutagenesis, the former is considered as more controversial among the public (Batista et al. 2008). Further work is desirable to assess the reasons for such perception patterns, however, possible explanations are that the mutagenesis is less well known by the public and/or less well communicated to the public.

The food processing method, i.e., edible coating which is often used in the fresh-cut fruit and vegetable industry, was perceived similarly to the gene editing technique, but more favourably than genetic modification and mutagenesis methods.

It is worth noting that the perception patterns among different methods were observed before survey respondents had been presented with any information about these novel food technologies. The later analysis on food choice data collected during the choice experiment (section 3.6.2) allows examining this perception pattern from a different perspective and within the context of a food purchase decision.

After reading detailed information on biotechnology and completing the choice experiment, respondents' evaluations of the *gene editing* technology were solicited with a set of attitudinal questions. They were asked to state the strength of their beliefs about the necessity, naturalness, morality, safety, benefits, risks, and so forth of using gene editing technology in food production (1=not at all, 6=extremely) (Appendix A question [GE\_1], [GE\_2]). Responses were averaged to form a single gene editing perception scale (Cronbach's  $\alpha = 0.92$ , all negatively framed items are reverse coded), with higher scores indicating more favourable attitudes towards gene editing technology. For the multivariate regression analysis in section 3.6.1, respondents whose perception scale values are greater than 4 were deemed as potential "supporters" for gene editing (35%), those whose scale values are less than 3 were deemed as potential "opponents" (34%), and the rest are "neutrals" (31%) (see Figure 3.6).



**Figure 3.6 Attitudes towards Gene Editing Technology in Food Production**

Data on respondents' cultural worldviews and relevant food technology attitudes are used in multivariate and choice analyses shown in section 3.6. In addition to collecting data on cultural worldviews and attitudes towards food biotechnology, the online 'Bio' survey also capture respondents' food choice behaviours by including a choice experiment. Respondents were asked to choose the most preferred food option from a set of hypothetical sliced apple product alternatives. The hypothetical 500g pre-packaged apple slices vary in levels of *appearance* (non-browning vs turn brown quickly), *health benefit* (contain regular vs. enhanced level of antioxidants), *production method* (two plant breeding methods – gene editing, genetic modification, and a food processing method – edible coating), and *price*.

Each respondent made six choices in total, and in each choice situation they were asked to select a most preferred alternative or opt to buy nothing. As such, the choice data consist of 4182 choice observations obtained from 697 respondents. The development of the choice experiment in this study, including the selection of attributes and levels, the partial constant design, and the efficient experiment design, have already been discussed in section 2.5 of chapter 2. Thus, for the sake of brevity, those discussions are not repeated here and section 3.5 proceeds by specifying the choice models estimated for this chapter.

### 3.5 Model Specification

This section specifies the choice models for estimation in this analysis. In particular, this chapter uses two models to analyze the choice data, a standard multinomial logit model and a random parameter logit model with error components.

#### 3.5.1 Multinomial Logit Model

The discrete choice modelling approaches are based on the random utility framework developed by McFadden (1974). Let  $U_{nsj}$  be the utility that individual  $n$  will derive from alternative  $j$  in choice set  $s$ . Further, utility  $U_{nsj}$  can be partitioned into two components: a systematic or observed component,  $V_{nsj}$ , and a random or unobserved component,  $\varepsilon_{nsj}$ .

$$U_{nsj} = V_{nsj} + \varepsilon_{nsj} \quad j = 1, 2, \dots, J \quad s = 1, 2, \dots, S \quad n = 1, 2, \dots, N \quad (3.1)$$

Since each individual defines utility in terms of attributes (Lancaster 1966), the systematic component of utility can be further expanded into  $K$  variables (or attributes,  $X_{nsjk}$ ). Assuming utility is linear in attributes and associated parameters, the utility function will take the form

$$U_{nsj} = x'_{nsj}\beta + \varepsilon_{nsj} = \sum_{k=1}^K \beta_k x_{nsjk} + \varepsilon_{nsj} \quad (3.2)$$

Where  $x_{nsj}$  is a vector of  $K$  explanatory variables including the attributes describing alternatives, characteristics of decision makers (e.g., gender, income), and variables related to the decision context (e.g., different information treatments).  $x_{nsj}$  may also contain up to  $J-1$  alternative specific constants (ASCs), taking a value of 1 for the alternative under consideration and 0 otherwise. The ASCs capture the average effects of unobserved or un-modelled factors on the utility for a particular alternative, and the  $J$ th ASC has to be normalized to zero for identification purposes.

$\beta$  is the vector of preference parameters to be estimated, reflecting the marginal (dis)utilities of attributes or the influences of covariates on utility. The randomness ( $\varepsilon_{nsj}$ ) in utility arises from the fact that researchers cannot fully represent all the influencing factors of preferences and utilities or completely observe the choice rules individuals adopt in decision-making (Louviere, Hensher and Swait 2000). In a standard multinomial logit (MNL) model, this unobserved component is assumed to be identically and independently distributed (i.i.d.) as type 1 extreme value (EV1).

Due to the random nature of utility specification, individuals' choices can be explained only up to a probability level (Louviere, Hensher and Swait 2000). A utility maximizer would choose the alternative that yields the highest utility level. That is, individual  $n$  would choose the  $i$ th alternative in choice set  $s$  if and only if when

$$U_{nsi} > U_{nsj} \quad \forall j \neq i \quad (3.3)$$

Combining with equation (3.1) and rearranging the equation yields

$$V_{nsi} - V_{nsj} > \varepsilon_{nsj} - \varepsilon_{nsi} \quad \forall j \neq i \quad (3.4)$$

Since  $\varepsilon_{nsi}$  and  $\varepsilon_{nsj}$  are both unobserved components, we compute the probability of individual  $n$  choosing alternative  $i$  in choice set  $s$  as

$$P_{nsi} = \text{Prob}(\varepsilon_{nsj} - \varepsilon_{nsi} < V_{nsi} - V_{nsj}) \quad \forall j \neq i \quad (3.5)$$

In MNL,  $\varepsilon_{nsj}$  and  $\varepsilon_{nsi}$  are assumed i.i.d. EV1 distributed, hence the choice probability is given by (see Train (2009, pp.74–75) for the mathematical derivation of logit choice probability):

$$P_{nsi} = \frac{\exp(V_{nsi})}{\sum_j \exp(V_{nsj})} = \frac{\exp(x'_{nsi}\beta)}{\sum_j \exp(x'_{nsj}\beta)} \quad (3.6)$$

$x_{nsj}$  is a vector of  $K$  observed variables and  $\beta$  is a vector of model parameters. This choice probability formula takes a closed form, thus it can be solved analytically using the traditional maximum likelihood procedures. In a choice experiment, it is common to ask each respondent to make a sequence of repeated choices. Assuming that each of these repeated choices are made independently by an individual, and each individual makes decisions independently from any other individuals, the probability of observing the choices made by a sampled population would be:

$$L(\beta) = \prod_n \prod_s \prod_i (P_{nsi})^{y_{nsi}} \quad (3.7)$$

where  $y_{nsi}$  is an indicator function taking value of 1 if individual  $n$  choose alternative  $i$  in choice set  $s$ , and 0 otherwise. The maximum likelihood estimation will solve for  $\hat{\beta}$  that maximizes the log-likelihood function as shown in equation (3.8):

$$LL(\beta) = \sum_n \sum_s \sum_i y_{nsi} \ln(P_{nsi}) \quad (3.8)$$

As stated earlier, the key assumption of MNL is the independence of error terms (i.e., the unobserved portion of utility  $\varepsilon_{nsj}$  is assumed to be i.i.d. EV1 distributed). As such, MNL is limited when the unobserved factors are in effect correlated across alternatives or over time in repeated choice situations.<sup>22</sup> Models allowing for more flexible error correlations are needed in order to accommodate any random preference (taste) variation, unrestricted substitution patterns across alternatives, and panel nature of choice data (Train 2009). In these cases, a random parameter logit model can be more appropriate.

### 3.5.2 Random Parameter Logit Model with Error Components

In the choice experiment, each respondent was asked to make a sequence of repeated choices (i.e., six choices per respondent). It would be more realistic to assume that the random, unobserved factors are correlated both across alternatives and over time in repeated choice situations. Also, we would expect preferences for attributes to vary across individuals based on their characteristics (e.g., cultural worldviews, income) and some unobserved factors. In these circumstances, a random parameter logit (RPL, also known as mixed logit) model that avoids the restrictive assumptions in MNL becomes more appropriate.

Recall in equation (3.2), preference parameters are assumed to be constant across individuals ( $\beta$ ). In RPL, however, preference parameters are allowed to vary across individuals as reflected by the subscript  $n$  in  $\beta_n$ :

$$U_{nsj} = x'_{nsj}\beta_n + \varepsilon_{nsj} = \sum_{k=1}^K \beta_{nk}X_{nsjk} + \varepsilon_{nsj} \quad (3.9)$$

$\beta_n$  is the individual-specific attribute parameter, representing individual  $n$ 's preferences. Suppose the preference parameters are distributed over individuals in a population with density  $f(\beta_n|\Omega)$ ,

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<sup>22</sup> As stated in Train (2009, pp.35–36), this independence assumption would be less restrictive once seen in another way. In a well-specified model, the observed portion of utility  $V_{nsj}$  should include all influencing factors such that the remaining unobserved portion of utility  $\varepsilon_{nsj}$  is essentially ‘white noise’. Hence, the appropriateness of MNL model depends on how well the utility is specified, and it is the ultimate goal for a researcher to specify the model sufficiently that only ‘white noise’ is left in  $\varepsilon_{nsj}$ . For this study, that is the reason for estimating a MNL model first, as it is used as an approximation under the current utility specification and serves as a benchmark for evaluating the suitability of model specification.

where  $\Omega$  are the parameters describing that distribution (e.g., mean and covariance). The conditional and unconditional choice probabilities are expressed in equation (3.10) and (3.11) respectively.

$$L_{nsi}(\beta_n) = \frac{\exp(x'_{nsi}\beta_n)}{\sum_j \exp(x'_{nsj}\beta_n)} \quad (3.10)$$

$$P_{nsi} = \int L_{nsi}(\beta_n) f(\beta_n|\Omega) d\beta_n = \int \frac{\exp(x'_{nsi}\beta_n)}{\sum_j \exp(x'_{nsj}\beta_n)} f(\beta_n|\Omega) d\beta_n \quad (3.11)$$

Different distributions,  $f(\beta_n|\Omega)$ , can be specified by researchers for preference parameters, such as normal, lognormal, and triangular distributions. However, as the integrals in equation (3.11) do not have a closed form, the probability has to be approximated through a simulation method:

$$\check{P}_{nsi} = \frac{1}{R} \sum_{r=1}^R L_{nsi}(\beta_n^r) \quad (3.12)$$

where  $\beta_n^r$  is the value of  $\beta_n$  in  $r$ th draw from the distribution of  $f(\beta_n|\Omega)$ . The logit probability is computed for each draw  $r$ , and the process repeated a total of  $R$  times. Taking the average of  $\beta_n^r$  values over  $R$  yields the simulated probability (Train 2009). Inserting the simulated probability into the log-likelihood function yields a simulated log-likelihood:

$$SLL(\beta_n|\Omega) = \sum_n \ln \left[ \frac{1}{R} \sum_{r=1}^R \prod_s \prod_i L_{nsi}(\beta_n^r)^{y_{nsi}} \right] \quad (3.13)$$

Maximizing the  $SLL$  function yields the maximum simulated likelihood estimator (MSLE):  $\hat{\Omega}$ , which are parameters of preference distribution (i.e., means and standard deviations) over individuals,  $f(\beta_n)$ .

The RPL relaxes the restrictive assumption of independence of error terms over alternatives and/or repeated choice situations. In particular, through specifying random parameters, we could accommodate any preference heterogeneity across individuals. In addition, error components are added to the RPL in model estimation to account for any ‘left-over’ preference heterogeneity that cannot be accounted for by random parameters, but rather is alternative-specific due to the ‘partially constant’ experimental design of the study.

In this study, the ‘conventional’ level of the ‘production method’ attribute appears only in the third alternative in each choice set, and this alternative does not exhibit any apple benefits such as ‘non-browning’ or ‘enhanced level of antioxidants’. By contrast, the first two alternatives in each choice set are ‘novel’ as they are associated with only novel food technologies – ‘gene editing’, ‘genetic modification’, or ‘edible coating’, and exhibit at least one of the apple characteristics. Even though the price level in the ‘constant’ third alternative could vary, this ‘partially constant’ design resembles the choice experiment design with a status-quo alternative, which usually consists of attribute levels that respondents are more familiar with.

As shown in Scarpa, Ferrini and Willis (2005), individuals evaluate status-quo systematically differently from those alternatives involving changes. Such behavioural patterns are supported by the behavioural insights that people are cognitive misers: when choosing among alternatives under uncertainty, they tend to stick with the default or status-quo option, and this tendency is unexplained by the variations in actual attribute levels across alternatives (Kahneman 2003). Respondents may perceive the cognitive task of evaluating all alternatives with novel food attributes and technologies as difficult, thus they are inclined to select the option that seems more familiar rather than engaging in the costly cognitive task.

In the context of novel food technologies, people may also exhibit loss aversion as they perceive the disadvantages of leaving the status-quo (i.e., the constant ‘conventional’ alternative) as greater than the advantages. Thus, respondents may want to stick with the ‘conventional’ alternative without deliberately considering the actual characteristics and outcomes associated with ‘novel’ alternatives (Lusk, Roosen and Bieberstein 2014).

Since respondents are more experienced and familiar with the attribute levels in the third ‘conventional’ alternative, respondents are expected to perceive and evaluate this alternative systematically differently from the first two hypothetical alternatives associated with some ‘novel’ characteristics.

There exist several ways to account for this systematic difference in preferences. First, alternative specific constants can be introduced to the utility function. As such, the systematic effect of the constant ‘conventional’ alternative versus the ‘novel’ alternatives can be addressed. Second, I postulate that the preference structure for two ‘novel’ alternatives are more similar to each other than it is to the ‘conventional’ alternative. That is, the utilities of ‘novel’ alternatives are correlated

to each other, and such correlation structure differs with that of other alternatives. In order to induce such correlation patterns across utilities of different alternatives, I add error components to RPL model, which has been proven an efficient method to account for status-quo effects and outperforms many other methods such as a nested logit model (Greene and Hensher 2007; Scarpa, Ferrini and Willis 2005).

As shown in equation (3.14), an additional alternative specific unobserved error component,  $\eta_{nsj}$ , is introduced into the utility function:

$$U_{nsj} = V_{nsj} + \eta_{nsj} + \varepsilon_{nsj} \quad (3.14)$$

Where  $\eta_{nsj}$  is assumed to follow the zero-mean normal distribution across the sampled population with a standard deviation  $\sigma$  to be estimated.  $\varepsilon_{nsj}$  are i.i.d. EV1 distributed with means of  $\gamma \approx 0.5772$  and variance of  $\pi^2/6$ . The utilities of two ‘novel’ alternatives share some form of covariance, thus they share the same error component  $\eta_{novel}$ ; while the error components associated with the third ‘conventional’ alternative and the fourth ‘no-purchase’ option are  $\eta_{conventional}$  and  $\eta_{no-purchase}$ , respectively.

The specification of RPL with error components leads to an error covariance structure across alternatives as follows:

$$\begin{pmatrix} \sigma_{novel}^2 + \pi^2/6 & \sigma_{novel}^2 & 0 & 0 \\ \sigma_{novel}^2 & \sigma_{novel}^2 + \pi^2/6 & 0 & 0 \\ 0 & 0 & \sigma_{conventional}^2 + \pi^2/6 & 0 \\ 0 & 0 & 0 & \sigma_{no-purchase}^2 + \pi^2/6 \end{pmatrix} \quad (3.15)$$

In sum, the RPL with error components model entails accounting for repeated choices, breaking away from the IIA assumption, and addressing unobserved preference heterogeneity. Additionally, the added error components induce different correlation patterns between the utilities of ‘novel’ alternatives and the constant ‘conventional’ alternative. As such, the choice model captures additional sources of preference heterogeneity that is not accounted for by the random parameters.

### 3.5.3 Full Model Specifications

The main objective of this study is to investigate the effects of cultural values on individuals’ preferences and evaluations of novel food technologies. There are several ways to introduce the



measures of cultural value into the utility model. The preference for each attribute, such as the health benefit offered and the technology applied in food production, may vary across individuals based on their cultural values or other characteristics. A standard multinomial logit (MNL) model has a limited ability in handling such preference (taste) variation: only systematic variation associated with observed variables can be incorporated in the MNL (Train 2009). When preferences (taste) varies purely randomly or with unobserved variables, a random parameter logit (RPL) model will be used instead.

In the MNL, measures of cultural values ( $CV_n$ ), including scores of hierarchy-egalitarianism ( $HE_n$ ) and individualism-communitarianism ( $IC_n$ ), enter the utility function through interaction terms as shown in equation (3.16):

$$U_{nsj} = \beta_{NB} \times NB_{nsj} + \beta_{AE} \times AE_{nsj} + (\beta_{GE} + \gamma_{GE \times HE} HE_n + \gamma_{GE \times IC} IC_n) \times GE_{nsj} + (\beta_{GM} + \gamma_{GM \times HE} HE_n + \gamma_{GM \times IC} IC_n) \times GM_{nsj} + (\beta_{EC} + \gamma_{EC \times HE} HE_n + \gamma_{EC \times IC} IC_n) \times EC_{nsj} + \beta_{PRI} \times PRI_{nsj} + \varepsilon_{nsj}, \quad j = 1, 2, 3$$

$$U_{nsj} = \beta_j + \varepsilon_{nsj}, \quad j = 4 \quad (3.16)$$

$\beta_{NB}$ ,  $\beta_{AE}$ ,  $\beta_{GE}$ ,  $\beta_{GM}$ ,  $\beta_{EC}$ , and  $\beta_{PRI}$  are the preference parameters (marginal (dis)utilities) of attributes non-browning ( $NB$ ), antioxidant-enhanced ( $AE$ ), gene-editing ( $GE$ ), genetic modification ( $GM$ ), edible coating ( $EC$ ) and price ( $PRI$ ).  $\beta_j$  is the alternative specific constant (ASC).  $\gamma_{GE \times HE} \dots \gamma_{EC \times IC}$  are marginal effects of interaction terms, which capture the effects of cultural values on marginal utilities.  $\varepsilon_{nsj}$  is assumed to be i.i.d. EV1 with mean of  $\gamma \approx 0.5772$  and variance of  $\pi^2/6$ .

In the RPL, preference heterogeneity is captured by random parameters. In this study, cultural values are assumed to influence the means of preferences for attributes of novel food technologies. As shown in the utility function (3.17) below,

$$U_{nsj} = \beta_{n,NB} \times NB_{nsj} + \beta_{n,AE} \times AE_{nsj} + \beta_{n,GE} \times GE_{nsj} + \beta_{n,GM} \times GM_{nsj} + \beta_{n,EC} \times EC_{nsj} + \beta_{PRI} \times PRI_{nsj} + \eta_{novel} + \varepsilon_{nsj}, \quad j = 1, 2$$

$$U_{nsj} = \beta_{n,NB} \times NB_{nsj} + \beta_{n,AE} \times AE_{nsj} + \beta_{n,GE} \times GE_{nsj} + \beta_{n,GM} \times GM_{nsj} + \beta_{n,EC} \times EC_{nsj} + \beta_P \times P_{nsj} + \eta_{conventional} + \varepsilon_{nsj}, \quad j = 3$$

$$U_{nsj} = \beta_j + \eta_{no-purchase} + \varepsilon_{nsj}, \quad j = 4 \quad (3.17)$$

the individual-specific random parameters are defined as functions of cultural values  $CV_n$ , including  $HE_n$  and  $IC_n$ .

$$\begin{aligned} \beta_{nk} &= \beta_k + \Delta_{k \times HE} HE_n + \Delta_{k \times IC} IC_n + \sigma_k v_{nk}, & k = GE, GM, EC \\ \beta_{nk} &= \beta_k + \sigma_k v_{nk}, & k = NB, AE, PRI \end{aligned} \quad (3.18)$$

Where  $\beta_k$  is the fixed portion of mean preference for attribute  $k$ , which keeps constant over individuals.  $\Delta_{k \times HE} HE_n$  and  $\Delta_{k \times IC} IC_n$  capture the observed heterogeneity around the mean of random parameters.  $v_{nk}$  is the random or unobserved component of preference, i.e., a random variable with zero mean and a known variance, thus it captures any unobserved preference heterogeneity. This study assumes that the random parameters of all non-price attributes are standard normally distributed, and the price parameter follows a constrained triangular distribution to preserve a behaviourally plausible (i.e., negative) sign over the entire sampled population.<sup>23</sup>

$$\begin{aligned} v_{nk} &\sim N[0,1] & \text{for } k = NB, AE, GE, GM, EC \\ v_{nk} &\sim \text{triangle}[-1,1] \text{ and } \sigma_k = \beta_k & \text{for } k = PRI \end{aligned} \quad (3.19)$$

The error components included in the utility model –  $\eta_{novel}$ ,  $\eta_{conventional}$ , and  $\eta_{no-purchase}$  – are assumed to be normally distributed with zero means and standard deviations ( $\theta_m$ ) to estimate.

$$Var(\eta_m) = \theta_m^2, \quad m = novel, conventioanl, no - purchase \quad (3.20)$$

Where  $\theta_m$  represents the standard deviation of an error component. Based on the preceding specifications, the simulated log-likelihood function is:

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<sup>23</sup> The *a priori* assumption is that the parameter estimate for the price attribute is negative for all individuals. Several distributions allow us to force the negative sign of the price parameter, including the commonly used lognormal, exponential, and constrained (one-sided) triangular distribution as chosen in this study. However, specifying the price parameter as a one sided triangular distribution is more plausible as it overcomes the problematic long and thick tail of a lognormal distribution (see Hensher, Rose and Greene (2015) for a detailed discussion).

In a constrained triangular distribution,  $\beta_n = \beta + \beta v_n$ , where  $v_n \sim \text{triangle}[-1,1]$ . This specifies that the two end points of the distribution are fixed at zero and  $2\beta$ , with  $\beta$  can be positive or negative. Thus, it ensures that the entire distribution of price parameter satisfies the one (negative) sign.

$$SLL(\beta_n|\Omega) = \sum_n \ln \left[ \frac{1}{R} \sum_{r=1}^R \prod_s \prod_i L_{nsi}(\beta_n^r)^{y_{nsi}} \right]$$

$$\text{where } L_{nsi}(\beta_n^r) = \frac{\exp[x'_{nsi}(\beta + \Delta CV_n + \sigma v_n^r) + \eta_m^r]}{\sum_j \exp[x'_{nsj}(\beta + \Delta CV_n + \sigma v_n^r) + \eta_m^r]} \quad (3.21)$$

### 3.6 Results and Discussion

This section examines effects of cultural values on both attitudes and choice behaviours related to novel food technologies. Section 3.6.1 presents results of a multivariate regression analysis to measure the influence of cultural values on attitudes while controlling for other influences. Based on data collected from the choice experiment, Sections 3.6.2 and 3.6.3 assess effects of cultural values on respondents' preferences and willingness-to-pay (WTP) values for novel food attributes. To facilitate analysis and interpretation, Table 3.2 presents a list of variables and covariates included in the estimation procedures along with their coding structures.

**Table 3.2 Covariates and Coding Structure**

<b>Variable</b>	<b>Description</b>	<b>Coding</b>
<i><b>Attributes</b></i>		
NB	Non-browning	= 1 if apple slices do not turn brown quickly after being sliced; 0 otherwise
AE	Enhanced with antioxidants like Vitamin C	= 1 if apple slices are enhanced with higher level of dietary antioxidants; 0 otherwise
GE	Gene editing	= 1 if desirable apple traits are achieved through gene editing; 0 otherwise
GM	Genetic modification	= 1 if desirable apple traits are achieved through genetic modification; 0 otherwise
EC	Edible coating	= 1 if desirable apple traits are achieved by edible coating method; 0 otherwise
PRI	The price levels included in choice experiment for a 500g bag of apple slices, ranging from \$3.69 to \$4.89	Continuous
<i><b>Covariates</b></i>		
HE	Average cultural value score derived from six Hierarchy-Egalitarian scale items	Continuous
IC	Average cultural value score derived from six Individualism-Communitarianism scale items	Continuous
Sci	Attitudes to science and technology in general: = 1 if consider ‘the world is a lot worse off’ because of science and technology; = 6 if consider ‘the world is a lot better off’ because of science and technology	Continuous
Risk	Indicator variable for the risk perception of food biotechnology	= 1 if perceive the risks of biotechnology outweigh its benefits; 0 otherwise
Age	Age in years	Continuous
University	Indicator variable for the highest educational attainment	= 1 if obtain a university degree or higher; 0 otherwise

Income	Indicator variable for the annual household income before taxes	= 1 if the annual combined household income before taxes is greater than \$80,000; 0 otherwise
Quebec	Indicator variable for province of residence	= 1 if reside in Quebec; 0 otherwise
Kid	Indicator variable for living with children	= 1 if children under 18 years old live in household; 0 otherwise
<b><i>Interactions</i></b>		
GE×HE	An interaction between GE and HE	—
GE×IC	An interaction between GE and IC	—
GM×HE	An interaction between GM and HE	—
GM×IC	An interaction between GM and IC	—
EC×HE	An interaction between EC and HE	—
EC×IC	An interaction between EC and IC	—

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### 3.6.1 Multivariate Regression Analysis

This section explores the roles of cultural values in shaping attitudes towards agricultural biotechnology. This section tests the first hypothesis ( $H_1$ ) that individuals holding relatively hierarchical and/or individualistic cultural values tend to support and perceive biotechnology more favorably, compared with individuals holding egalitarian and/or communitarian worldviews. In particular, it aims to understand the driving factors for individuals being “supporters”, “opponents”, or “neutrals” of gene editing technology. As shown in Figure 3.6, based on their responses to a set of attitudinal questions, 35% of sampled Canadians are classified as “supporters”, 34% are “opponents”, and the rest 31% are ‘neutrals’ for the gene editing technology. An ordered probit model is estimated since the dependent variable has a natural ordering (i.e., attitudes towards gene editing become more favourable as moving from ‘opponents’, ‘neutrals’, to ‘supporters’).

Explanatory variables include two cultural value scores developed in section 3.4.1 (Hierarchy-Egalitarianism (*HE*) and Individualism-Communitarianism (*IC*)), views on science and technology in general (*Sci*), risk perception of biotechnology (*Risk*), and socio-demographic variables (*Age*, *University*, *Income*, *Quebec*, and *Kid*). Table 3.3 presents the estimation results of the ordered probit model.

**Table 3.3 Factors Affecting Attitudes towards Gene Editing Technology**

Variable	Model Estimates		Marginal Effects					
	Par.	Std. Err.	Supporters		Neutrals		Opponents	
			Par.	Std. Err.	Par.	Std. Err.	Par.	Std. Err.
<i>HE</i>	0.105**	0.048	0.031**	0.014	-0.004**	0.002	-0.028**	0.013
<i>IC</i>	-0.058	0.056	-0.017	0.017	0.002	0.002	0.015	0.015
<i>Sci</i>	0.322***	0.048	0.096***	0.013	-0.011***	0.003	-0.085***	0.012
<i>Risk</i>	-1.334***	0.111	-0.382***	0.026	-0.064***	0.020	0.446***	0.037
<i>Age</i>	-0.007*	0.004	-0.002*	0.001	0.000	0.000	0.002*	0.001
<i>University</i>	0.047	0.104	0.014	0.031	-0.002	0.003	-0.013	0.028
<i>Income</i>	-0.098	0.104	-0.029	0.031	0.003	0.004	0.026	0.027
<i>Quebec</i>	-0.292**	0.115	-0.086***	0.033	0.006**	0.003	0.079**	0.032
<i>Kid</i>	-0.232*	0.130	-0.068*	0.037	0.005**	0.003	0.063*	0.036
<i>Cutoff Value_1</i>	0.183	0.396						
<i>Cutoff Value_2</i>	1.209	0.398						
<i>Log likelihood</i>				-568.324				
<i>AIC</i>				1158.647				
<i>BIC</i>				1207.655				
<i># of Par.</i>				11				
<i>N</i>				636				

Notes: 1. \*, \*\*, and \*\*\* indicate parameters are significantly different from zero at the levels of 10%, 5%, and 1%, respectively.

2. Number of respondents included in this analysis is 636 rather than the full sample size of 697, due to missing data for socio-demographic variables.

Results indicate that, holding all else constant, hierarchical worldview tends to induce more favourable attitudes towards gene editing technology as the *HE* parameter is positive and significant. According to the marginal effects estimates, respondents holding relatively hierarchical worldviews are more likely to be supporters of gene editing, while less likely to be neutrals and opponents, compared with those holding egalitarian worldviews. Attitudes towards gene editing, however, do not differ significantly between people holding individualistic vs. communitarian worldviews, as the estimated parameter for *IC* variable is negative but *insignificant*.

As such, H<sub>1</sub> is only partially supported by the results. As shown later in the choice analysis (section 3.6.2), similar effects of cultural values on preferences are identified for three food technologies. Hierarchists are disposed to hold favorable attitudes towards novel technology as acknowledging

its risks could threaten the competence of social and governmental elites, such as scientists and regulators who support technological advances. As posited in cultural cognition theory, individualists believe that individual interests are the most important and should override social welfare. If individualists do not perceive gene editing as offering substantial benefits at an individual level (i.e., providing tangible and direct benefits to individuals), they would hold relatively more negative attitudes towards and hence are less likely to support gene editing. By contrast, communitarians tend to debase any self-interest seeking behaviours and believe collective interests should take precedence. Gene editing may be perceived by communitarians as providing substantial collective benefits to society as whole (e.g., reducing food waste or food processing costs, encouraging healthier food choices), as such, they are more likely to support it. This assumption, however, requires further research to investigate.

Additionally, results revealed that, all else being equal, positive attitudes towards science and technology in general tend to induce more favourable attitudes towards gene editing in particular (significantly positive *Sci* parameter). Marginal effects estimates suggest that positive science beliefs increase the likelihood of being supporters of gene editing relative to neutrals and opponents. That is, individuals' attitudes towards gene editing significantly relate to their views on science and technology in general. This finding is consistent with Vandermoere et al. (2010; 2011) who revealed that more positive (negative) attitudes toward science and technology would increase the likelihood of being optimistic (negative) about food nanotechnology among sampled German and French respondents, respectively.

It is also found that individuals' risk perceptions with respect to biotechnology (*Risk* variable) have significant impacts on their attitudes towards gene editing technology: respondents who believe the risks of biotechnology outweighs its benefits are more likely to be opponents of gene editing and are less likely to be supporters or neutrals. The significant role of risk (and benefit) perceptions in biotechnology attitude formation has also been revealed in previous studies (Costa-Font, Gil and Traill 2008; Moon and Balasubramanian 2004). For example, based on a large survey data collected in the US and UK, Moon and Balasubramanian (2004) revealed that risk perceptions play a greater role than benefit perceptions in shaping public biotechnology attitudes.

Results suggest that older respondents (*Age*), Quebec residents (*Quebec*), and those having children living in the household (*Kid*) are less likely to be supportive and more likely to be

opposing or neutral toward gene editing, *ceteris paribus*. Similarly, Magnusson and Hursti (2002) and Hallman et al. (2003) found that younger people were in general more likely to approve genetically modified foods compared with older subjects. There are also studies that identified insignificant age impacts, such as Verdurme and Viaene (2003). In the dataset, other socio-demographics such as education (*University*) and income (*Income*) levels have no significant influences on consumers' attitudes to gene editing.

In sum, the multivariate analysis suggests that individuals' cultural worldviews play an important role in affecting their attitudes towards biotechnology, with the first hypothesis ( $H_1$ ) being partially supported. The next section presents estimation results from the choice data, which explore the effects of cultural values by examining their influences on a food purchase decision.

### 3.6.2 Discrete Choice Modelling

This study includes a choice experiment in order to test the second hypothesis ( $H_2$ ) developed in section 3.3 that individuals holding relatively hierarchical and/or individualistic cultural worldviews are more likely to purchase foods produced encompassing a novel food technology (e.g., biotechnology), compared with individuals holding egalitarian and/or communitarian worldviews. Choice behaviours captured in the choice experiment allow examining whether underlying cultural values have impacts on individuals' preferences for different novel food attributes. In the choice experiment, respondents were asked to make 6 choices of sliced apple products that vary in features, including appearance, health benefit, production method and price. By observing respondents' choices, this study could understand how respondents value and make tradeoffs between different novel food attributes.

As specified in section 3.5, choice data are analyzed by a standard multinomial logit (MNL) model and a random parameter logit (RPL) model with error components. Both models are estimated in Nlogit 6 (Econometric Software Inc.). The MNL model is estimated by the maximum likelihood method, and the RPL model is estimated by maximum simulated likelihood with 1000 Halton draws.<sup>24</sup> Table 3.4 presents the estimation results.

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<sup>24</sup> As discussed in Train (Train 2009), with a sufficiently large  $R$  number of draws, the simulated function will provide an adequate approximation to the actual function for likelihood based estimation. Also, fewer numerous intelligent draws could give empirically similar results to



**Table 3.4 Choice Model Results**

	MNL		RPL	
			<i>Random Parameters</i>	
<b>Mean</b>	Coeff.	Std. Err.	Coeff.	Std. Err.
NB	0.694***	0.070	1.304***	0.196
AE	0.158**	0.065	0.332*	0.176
GE	-1.127***	0.195	-1.532*	0.794
GM	-1.074***	0.218	-1.503**	0.737
EC	-0.997***	0.209	-1.092	0.864
PRI	-0.658***	0.038	-1.757***	0.081
			<i>Non-random Parameters</i>	
No-purchase	-3.375***	0.167	-10.710***	0.515
<b>Mean Shifter</b>				
GE×HE	0.121***	0.045	0.203	0.188
GE×IC	-0.047	0.053	-0.225	0.221
GM×HE	0.244***	0.053	0.494***	0.186
GM×IC	-0.290***	0.062	-0.723***	0.211
EC×HE	0.149***	0.050	0.404*	0.223
EC×IC	-0.210***	0.058	-0.772***	0.253
<b>Standard Deviation</b>				
$\sigma_{NB}$			2.595***	0.218
$\sigma_{AE}$			2.156***	0.194
$\sigma_{GE}$			1.551***	0.227
$\sigma_{GM}$			1.120***	0.302
$\sigma_{EC}$			2.482***	0.220
$\sigma_{PRI}$			1.757***	0.081
<b>Error Components</b>				
$\theta_{novel}$			1.579***	0.366
$\theta_{conventional}$			3.287***	0.302
$\theta_{no-purchase}$			6.311***	0.490
<b>Model Fit</b>				
Log likelihood	-5359.4		-3560.4	
AIC/N	2.569		1.713	
BIC/N	2.589		1.745	

numerically larger numbers of random draws (Hensher, Rose and Greene 2015). For this reason, I use Halton draws rather than random draws to speed up and smooth the simulations.

Pseudo R <sup>2</sup>	0.076	0.386
No. of Parameters	13	22

Notes: 1. Number of respondents = 697.

2. Number of choices observed = 4182.

3. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

The MNL model can only accommodate preference heterogeneities that are associated with observable individual characteristics. As such, respondents' cultural value scores enter the model via interaction terms, as shown in equation (3.16)<sup>25</sup>. The overall fit of the MNL is  $-5359.4$ , which is a statistically significant improvement over the no-parameters base model (i.e., model without any predictors, i.e., all slope parameters are set to zero) fit of  $-5797.5$  (Likelihood Ratio Test ( $LRT$ ) =  $-2 \times (-438.1) = 876.2$ , which is greater than the critical  $\chi^2$  value at 1% level with 10 degrees of freedom of 23.209). Thus, the MNL model is overall statistically significant.

Most model parameters from the MNL analysis are significant, except for the interaction term between gene editing (*GE*) and Individualism-Communitarianism (*IC*). The significantly positive parameters associated with non-browning (*NB*) and antioxidant-enhanced (*AE*) attributes indicate that consumers perceive these consumer-oriented apple characteristics as preferable, holding all else equal. All three novel food technologies – gene editing (*GE*), genetic modification (*GM*), and edible coating (*EC*) – are less preferred than the conventional production method, *ceteris paribus*. All else being equal, higher price (*PR*) levels induce lower utilities, and respondents in the sample are more likely to choose from one of the three alternatives offered in the choice experiment rather than buying nothing, as the indicator variable, *No-purchase*, is associated with a significantly negative estimate.

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<sup>25</sup> To account for potential differences in cultural worldviews between respondents from Quebec and the rest of Canada (see Appendix 3.II Table 3.A4), a MNL model including an additional demographic variable (*Quebec*) is also estimated in Appendix 3.II Table 3.A5.

Also, as hypothesized in H<sub>2</sub> and specified in equation (3.16), cultural worldviews shift preferences for the three novel food technologies included in this study – gene editing (*GE*), genetic modification (*GM*), and edible coating (*EC*). Model results shown in Table 3.4 only include interactions between the three technologies (*GE*, *GM*, *EC*) and cultural worldviews (*HE*, *IC*). To investigate if cultural worldviews also have impacts on preferences for the other two novel food attributes – non-browning (*NB*) and antioxidant-enhanced (*AE*) – I also run the MNL and RPL models with additional interaction terms between the two apple attributes (*NB*, *AE*) and cultural worldviews (*HE*, *IC*). Estimation results are presented in Appendix 3.III, Table 3.A6.

The RPL model assumes that all non-price attribute parameters are random with a normal distribution. The price parameter is also random but with a constrained (one-sided) triangular distribution to ensure the behaviourally meaningful (negative) sign for estimates across entire distribution. All random parameters are estimated using 1000 Halton draws.

The RPL model outperforms the MNL model since the log-likelihood ( $LL$ ) function at convergence is  $-3560.4$ , compared with  $-5359.4$  for the MNL model. The likelihood ratio test ( $LRT$ ) gives  $-2 \times (-1799) = 3598$ , which is greater than the critical  $\chi^2$  value at 1% level with 9 degrees of freedom, 21.666. The AIC/BIC values and pseudo- $R^2$  all dramatically improved when moving from the MNL to the RPL model.

Estimates of standard deviations for *all* attribute variables are statistically significant, indicating the existence of preference heterogeneity. That is, respondents are heterogeneous in their preferences for all attributes. In addition, as discussed in section 2.5 in chapter 2, due to the ‘partially constant’ experimental design, the third alternative in all choice sets possess only ‘conventional’ levels of attributes. That is, the third alternative is always apple slices that turn brown quickly, not being enhanced with antioxidants, and being produced by a conventional production method, while price levels can vary. By contrast, the first two alternatives in all choice sets are described by unfamiliar attribute levels: apple slices produced with one of three food technologies ( $GE$ ,  $GM$ , or  $EC$ ) and hence exhibit at least one novel apple characteristics ( $NB$ ,  $AE$ , or both). As a result, I postulate that individuals may treat the third ‘conventional’ alternative systematically differently than the other two ‘novel’ alternatives, as respondents are more familiar with the ‘conventional’ attribute levels.

Error terms are added to the RPL model to capture such additional unobserved heterogeneity that is alternative specific. In the study, three error components are assumed to be normally distributed across the sampled population with zero means and standard deviations to be estimated. The data show evidence for such a ‘status quo’ effect as all standard deviation effects are statistically significant. That is, there is a noticeable amount of preference heterogeneity associated with each choice alternative that is not accounted for by the random parameters of apple attributes.

Results suggest that heterogeneity (or equivalently, standard deviation of the error component) across sampled population is largest for the opt-out option ( $\theta_{no\_purchase}$ ), followed by the

‘conventional’ alternative ( $\theta_{conventional}$ ), and heterogeneity for the ‘novel’ alternatives is the least ( $\theta_{novel}$ ). Similar results are also identified by Scarpa, Ferrini and Willis (2005), who revealed a systematic and significant difference in perception and substitutability between *experimentally designed* alternatives and *experienced status-quo* alternative. Compared with the first two ‘novel’ alternatives in each choice set, the third ‘conventional’ alternative contains attribute levels with which respondents are more familiar. For this reason, heterogeneity across the population is greater for the ‘conventional’ alternative than for the ‘novel’ alternatives.

Marginal utilities associated with each attribute are calculated by taking into account interaction terms. As such, we can compare respondents’ (average) preferences for different novel food technologies. Table 3.5 presents the expressions and computations of marginal utilities in both models.

**Table 3.5 Marginal Utilities for Individual Attributes**

	MNL			RPL		
	Expressions	Estimates		Expressions	Estimates	
		Mean <sup>1</sup>	Std. Err.		Mean <sup>2</sup>	Std. Dev. <sup>3</sup>
NB	$\beta_{NB}$	0.694 <sup>***4</sup>	0.070	$\beta_{NB} + \sigma_{NB}N_{NB}$	1.334 <sup>***</sup>	2.614
AE	$\beta_{AE}$	0.158 <sup>**</sup>	0.065	$\beta_{AE} + \sigma_{AE}N_{AE}$	0.350 <sup>***</sup>	2.149
GE	$\beta_{GE} +$ $\gamma_{GE \times HE}HE_n +$ $\gamma_{GE \times IC}IC_n$	-0.980 <sup>***</sup>	0.093	$\beta_{GE} + \Delta_{GE \times HE}HE_n +$ $\Delta_{GE \times IC}IC_n + \sigma_{GE}N_{GE}$	-1.833 <sup>***</sup>	1.570
GM	$\beta_{GM} +$ $\gamma_{GM \times HE}HE_n +$ $\gamma_{GM \times IC}IC_n$	-1.492 <sup>***</sup>	0.099	$\beta_{GM} + \Delta_{GM \times HE}HE_n +$ $\Delta_{GM \times IC}IC_n + \sigma_{GM}N_{GM}$	-2.854 <sup>***</sup>	1.308
EC	$\beta_{EC} +$ $\gamma_{EC \times HE}HE_n +$ $\gamma_{EC \times IC}IC_n$	-1.374 <sup>***</sup>	0.097	$\beta_{EC} + \Delta_{EC \times HE}HE_n +$ $\Delta_{EC \times IC}IC_n + \sigma_{EC}N_{EC}$	-2.872 <sup>***</sup>	2.564
PRI	$\beta_{PRI}$	-0.658 <sup>***</sup>	0.038	$\beta_{PRI} + \sigma_{PRI}T_{PRI}$	-1.754 <sup>***</sup>	0.714

Notes: 1. In the MNL, to compute the mean marginal utility of an attribute, the expression is computed for each observation in the sample and then the average is taken.

2. In the RPL, to obtain the mean marginal utility, the population has to be first simulated by taking draws from the normal (for the non-price attributes) or the constrained one-sided triangular (for the price attribute) distribution. Then compute the value of expression for each observation and take the average.

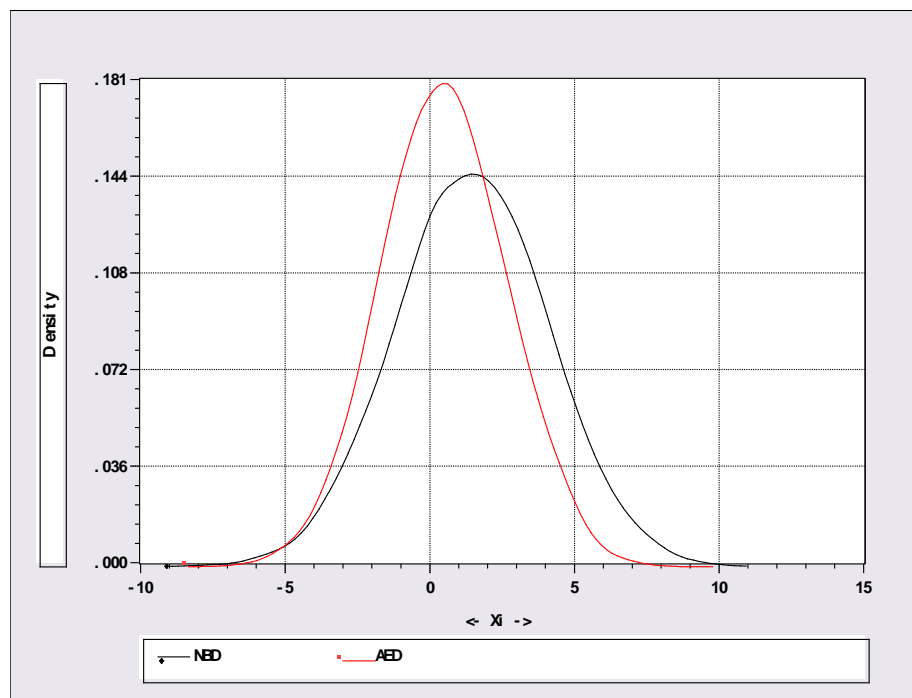
3. In the RPL, standard deviations for the marginal utility estimates are reported instead of standard errors for the same reason shown in footnote 15.

4. \*, \*\*, and \*\*\* indicate parameters are significantly different from zero at the levels of 10%, 5%, and 1%, respectively.

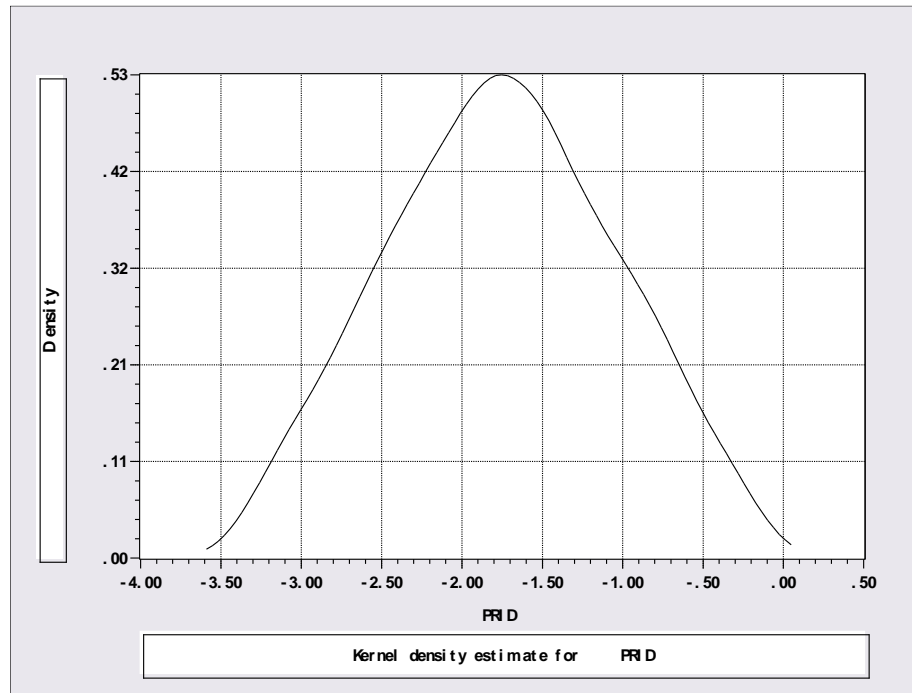
Results from both models show that the non-browning and antioxidant-enhanced characteristics are associated with significantly positive marginal utilities, i.e., consumers would prefer sliced apples to resist browning or contain enhanced levels of antioxidants, all else being equal. The price attribute in both models induces negative marginal utility, which indicates that a lower price level is preferred. In both models, all three novel food technologies – gene editing, genetic modification, and edible coating – are associated with negative marginal utilities. That is, using these technologies in sliced apple production is discounted by consumers, compared with using the conventional production method. The extent to which respondents discount these technologies however differs. Both models suggest that, *ceteris paribus*, gene editing is significantly less discounted by consumers than genetic modification and edible coating; while there is no significant difference between genetic modification and edible coating. This finding supports H<sub>3</sub> that gene editing technology is associated with a higher level of acceptance (or a lower level of resistance) by consumers as compared to genetic modification.

Additional to the above measures of mean marginal utilities, distributions of marginal utilities based on RPL model estimates are also presented in Figure 3.7.

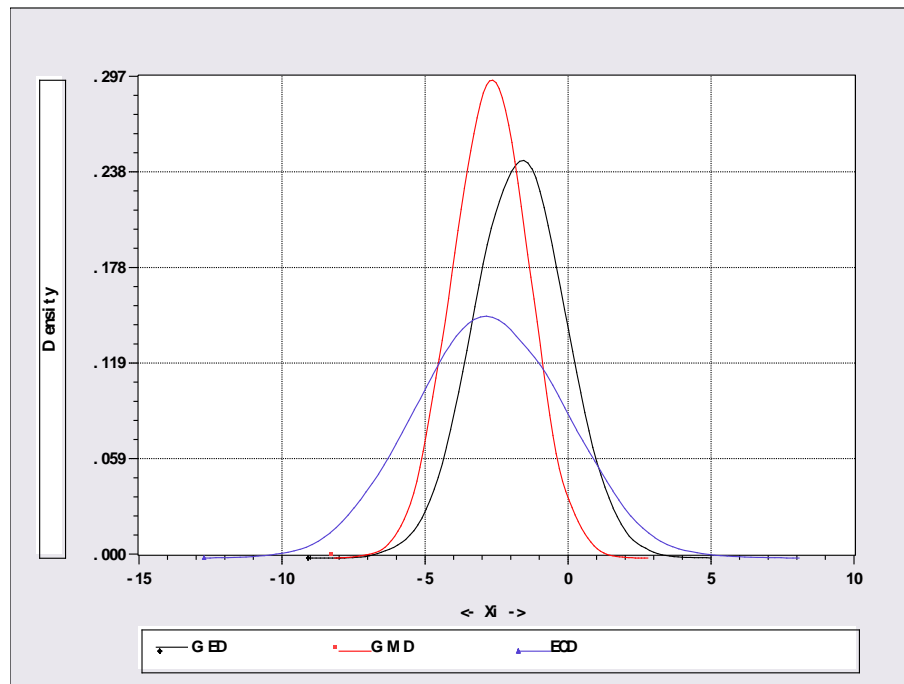
(a) NB and AE



**(b) PRI**



**(c) GE, GM, and EC**



**Figure 3.7 Distributions of Marginal Utilities for Each Attribute**

As shown in Figure 3.7 (a), a majority of sampled respondents value the non-browning characteristic, as the area of positive marginal utility under NB distribution is greater than 0.5. About a half of respondents view the antioxidant-enhanced characteristic positively (i.e., positive marginal utilities). The distribution of price as shown in Figure 3.7 (b) indicates that all sampled individuals have negative marginal utilities for the price attribute, and this is actually assured by assuming a constrained triangular distribution for the price parameter.

When comparing distributions of marginal utilities for gene editing, genetic modification, and edible coating, Figure 3.7 (c) reveals that all three technologies are discounted by most of the respondents, however, on average, genetic modification receives the least amount of support among respondents as the area of positive marginal utility under the GM distribution is the smallest.

To test cultural values effects on preferences for novel food technologies ( $H_2$ ), respondents' cultural value scores developed in section 3.4.1 entered both choice models through interaction terms (see equation (3.16) – (3.18)). Results of the MNL model indicate that hierarchical worldviews help to reduce the *disutilities* associated with three novel food technologies, as the estimates of *HE*-related interactions are all significant and positive. That is, as the score on the *HE* scale increases, the marginal *disutilities* (given the negative sign for the mean estimates) of three novel technologies – gene editing, genetic modification, and edible coating – will decrease. This finding supports  $H_2$  as individuals holding hierarchical worldviews are more likely to choose foods produced by novel technologies, compared with individuals holding egalitarian worldviews.

On the other hand, individualistic worldview tend to reinforce the negative preferences for novel technologies, as two of the three *IC*-related interactions ( $GM \times IC$  and  $EC \times IC$ ) are significant but negative. That is, individuals holding individualistic worldviews tend to exhibit weaker preferences for genetic modification and edible coating, compared with those holding communitarian worldviews. This finding, however, contradicts  $H_2$ . Recall that similar results were identified in the multivariate regression analysis in section 3.6.1. A possible explanation is that, individualists emphasize the importance of individual interests, however, they perceive little tangible and direct benefits offered by food technologies at individual levels. This is somehow consistent with the fact that biotechnology has been mostly targeted at farmers (e.g., developing crops with greater productivity or resistance to diseases and pests) and applied in processed food

ingredients that consumers cannot easily observe. Therefore, individualists are more likely to oppose food technologies than communitarians, who perceive greater collective benefits of novel food technologies to society as a whole. This assumption is worth further investigation.

It is also worth noting that both hypotheses ( $H_1$  and  $H_2$ ) are developed on the basis of cultural cognition theory, whose impacts have not been extensively examined in the food domain, although cultural value effects have been documented in many other disputed matters, such as nanotechnology, climate change, handgun use and vaccination (Kahan et al. 2007; Kahan et al. 2009; Kahan et al. 2010; Kahan, Jenkins-Smith and Braman 2011). As such, the findings suggest that the effects of cultural values may vary depending on the research context. In particular, influences of cultural values on perceptions and behaviours in the food domain could dramatically differ with those in other contexts.

RPL results indicate similar cultural value effects. *Ceteris paribus*, the hierarchical worldview tends to increase the marginal utilities of genetic modification and edible coating as the parameters of these interactions are significantly positive. An individualistic worldview induces lower marginal utilities for genetic modification and edible coating as parameters of these interaction terms are significant and negative. As such, the second hypothesis ( $H_2$ ) is only partially supported by the data.

For a closer look at cultural value effects, I also investigate how people belonging to different cultural groups would perceive three novel food technologies. Respondents were classified as either ‘Hierarchists’ or ‘Egalitarians’, and as either ‘Individualists’ or ‘Communitarians’, depending on their cultural scores relative to the sample medians of each scale. For example, a respondent with a *HE* score greater than the sample median of the *HE* scale, would be designated as a ‘Hierarchist’, otherwise an ‘Egalitarian’. A respondent with *IC* score higher than the sample median of *IC* scale, would be designated as an ‘Individualist’, otherwise a ‘Communitarian’. Table 3.6 compares the (average) marginal utilities of three technologies across different cultural groups, based on RPL model estimates.



**Table 3.6 Marginal Utilities of Novel Food Technologies across Cultural Groups**

	<b>Gene Editing</b>	<b>Genetic Modification</b>	<b>Edible Coating</b>
<i>Population</i> <sup>1</sup>	-1.833 (1.570) <sup>2</sup>	-2.854 (1.308)	-2.872 (2.564)
<i>Hierarchists</i>	-1.707** (1.564) <sup>3</sup>	-2.638*** (1.285)	-2.788 (2.535)
<i>Egalitarians</i>	-1.950 (1.566)	-3.056 (1.298)	-2.950 (2.588)
<i>Individualists</i>	-1.930 (1.572)	-3.245*** (1.302)	-3.389*** (2.508)
<i>Communitarians</i>	-1.754 (1.563)	-2.541 (1.226)	-2.457 (2.532)

Notes: 1. The full sample size is 697. Respondents were designated as either 'Hierarchists' (n=337) or 'Egalitarians' (n=360), and either 'Individualists' (n=310) or 'Communitarians' (n=387), depending on the relationship of their scores with the sample medians of scales (sample median of *HE* scale is 2.5, and *IC* scale is 3.67).

2. Numbers shown in parentheses are standard deviations.

3. Pairwise t-test is used to compare the mean values of marginal utilities across cultural groups. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

Differences in marginal utilities between 'hierarchists' and 'egalitarians', as well as between 'individualists' and 'communitarians' are significant for most novel food technologies.<sup>26</sup> All else being equal, marginal utilities are shown to be less negative for 'hierarchists' as opposed to 'egalitarians'. That is, 'hierarchists' are more likely to value novel food technologies than 'egalitarians'. In addition, it is found that 'individualists' tend to discount novel technologies more than 'communitarians', as indicated by their greater negative mean marginal utilities. As such, results reveal that individuals belonging to different cultural groups possess different perceptions and preferences for food technologies, although results only partially support the hypothesis developed based on cultural cognition theory.

<sup>26</sup> In order to test the significance of differences in mean marginal utilities between cultural groups, I also run a regression in which individuals' marginal utilities are the dependent variable, while dummy variable 'Hierarchist' or 'Individualist' and a constant term are independent variables. For example,  $MU_{GE\_n} = Intercept + \beta \times 'Hierarchist'_n + \varepsilon$  and  $MU_{GE\_n} = Intercept + \beta \times 'Individualist'_n + \varepsilon$ . Results show that estimates associated with 'Hierarchist' or 'Individualist' are statistically significant at the 1% level for all three novel technologies. That is, being 'Hierarchist' or 'Individualist' has significant impacts on the marginal utilities of food technologies.

Overall, both choice models (i.e., MNL and RPL) suggest that consumers, all else being equal, on average, value the consumer-oriented apple characteristics – non-browning and antioxidant-enhanced – positively, although strong evidence shows the existence of preference heterogeneity among consumers. In addition, different novel food technologies – plant breeding methods (gene editing and genetic modification) or food processing method (edible coating) – could be used to introduce these characteristics into apple slices. Results show that individuals perceive and evaluate these technologies differently and heterogeneously, and one possible explanation for such heterogeneity is their underlying cultural worldviews.

On average, consumers prefer the conventional production method over all three novel technologies in the study. However, a closer look at the results reveals that respondents discount gene editing technology significantly less than genetic modification and edible coating, *ceteris paribus*. As such, H<sub>3</sub> is supported by the data. Such a finding could be attributed to the difference between individual technologies. The gene editing method usually involves making changes to plants' existing genes. By contrast, to obtain desired traits, genetic modification often requires inserting foreign genes from other species into a plant, and edible coating involves dipping food products into chemical solutions containing different additives. As such, consumers perceive these technologies as associated with distinct benefits and risks, and their preferences differ.

Both models reveal significant cultural value effects on preferences for food technologies, i.e., individuals' underlying cultural worldviews have significant impacts on how they respond to novel food technologies. Holding all else constant, people holding a relatively hierarchical worldview are less resistant to food technologies, compared with people holding an egalitarian worldview. This finding supports H<sub>2</sub> and is consistent with cultural cognition theory, which posits that hierarchists are disposed to hold favorable attitudes towards novel technology as acknowledging its risks could threaten the competence of social and governmental elites, such as scientists and regulators.

Additionally, people holding a relatively individualistic worldview are less likely to value novel food technologies, as opposed to people holding a communitarian worldview. This finding contradicts the hypothesis H<sub>2</sub> developed based on cultural cognition theory. One possible reason is that, although individualists emphasize the importance of individual interests over collective social welfare, they fail to perceive tangible and direct benefits of food technologies at individual

levels. As such, they are more likely to oppose technologies applied in foods, compared with communitarians who may believe food technologies could benefit society as a whole.

Although hypotheses  $H_1$  and  $H_2$  are only partially verified, study results provide significant insights that cultural value effects should be examined within different contexts, as their influences are found to differ significantly between food domain and other controversial matters. The next section continues exploring effects of cultural values on individuals' willingness-to-pay values for novel food technologies.

### 3.6.3 Willingness to Pay

This study also examines how respondents value individual food attributes. To derive the monetary value associated with each attribute, the utility function can be re-written in a simpler form consisting of an attribute of interest ( $X$ ), price attribute ( $PRI$ ), their associated parameters ( $\beta_X$  and  $\beta_{PRI}$ ), all other terms and a stochastic component ( $\varepsilon$ ).

$$U = \beta_X X + \beta_{PRI} PRI + other\ terms + \varepsilon \quad (3.22)$$

The willingness-to-pay (WTP) for an attribute is thus defined as the ratio of marginal utility of that attribute to marginal utility of the price attribute. In a linear-in-parameters model specification, WTP can be calculated as the ratio of the non-price attribute parameter to the price parameter:

$$WTP = \frac{\partial U / \partial X}{\partial U / \partial PRI} = \frac{\beta_X}{\beta_{PRI}} \quad (3.23)$$

The MNL model also includes interaction terms between attribute and cultural values to capture any observed sources of heterogeneity, hence, the formula for calculating WTP now takes the form in equation (3.24). The mean WTP is obtained by computing the value of WTP function for each observation in the sample and then taking the average.

$$WTP_k = \frac{\beta_k}{\beta_{PRI}} \quad for\ k = NB, AE$$

$$WTP_k = \frac{\beta_k + \gamma_{k \times HE} HE_n + \gamma_{k \times IC} IC_n}{\beta_{PRI}} \quad for\ k = GE, GM, EC \quad (3.24)$$

The RPL model explores the cultural value effects by allowing for random preference heterogeneity, with all non-price attribute parameters assumed to be standard normally distributed and the price attribute assumed to follow a constrained (one-sided) triangular distribution. The WTP functions would take similar forms as in the MNL, however, the population must be simulated first to obtain the WTP measure.

$$WTP_k = \frac{\beta_k + \sigma_k N_k}{\beta_{PRI} + \sigma_{PRI} T_{PRI}} \quad \text{for } k = NB, AE$$

$$WTP_k = \frac{\beta_{GE} + \Delta_{k \times HE} HE_n + \Delta_{k \times IC} IC_n + \sigma_k N_k}{\beta_{PRI} + \sigma_{PRI} T_{PRI}} \quad \text{for } k = GE, GM, EC \quad (3.25)$$

Table 3.7 shows the WTP results derived from the MNL and RPL models.

**Table 3.7 WTP Values for Attributes**  
(\$/500g prepackaged apple slices)

	MNL	RPL	Hierarchist	Egalitarian	$\Delta_{H-E}$	Individualist	Communitarian	$\Delta_{I-C}$
NB	1.055	1.059						
AE	0.240	0.300						
GE	-1.490	-1.461	-1.408	-1.511	0.103	-1.579	-1.367	-0.212**
GM	-2.269	-2.286	-2.193	-2.372	0.179*	-2.617	-2.021	-0.596***
EC	-2.089	-2.268	-2.206	-2.326	0.120*	-2.607	-1.997	-0.610***

Notes: 1. Pairwise t-test is used to compare the mean values of WTP values across cultural groups.  
2. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

WTP results under both the MNL and RPL models suggest that respondents are willing to pay a premium for non-browning (*NB*) and antioxidant-enhanced (*AE*) attributes.<sup>27</sup> The negative WTP values, however, represent the implicit WTP to avoid novel food technologies. For example, the RPL model indicates that, respondents are willing to pay \$1.461 more for a 500g bag of pre-packaged apple slices that are not produced with gene editing, and \$2.286 more to avoid genetically modified apple slices. Both choice models suggest that, on average, consumers are

<sup>27</sup> As shown in Table 3.A6 in Appendix 3.III, cultural worldviews do not have significant impacts on preferences for two novel apple characteristics – non-browning (*NB*) and antioxidant-enhanced (*AE*). For this reason, the willingness-to-pay (WTP) values for *NB* and *AE* should also not differ significantly across cultural worldview groups. Hence, WTP values for *NB* and *AE* are reported here without considering the cultural worldview differences.

willing to pay approximately 50% higher to avoid genetic modification and edible coating than to avoid gene editing.

Results also reveal significant cultural value effects on willingness-to-pay values. Similar with the method used when analyzing marginal utilities, WTP results are compared across different cultural groups based on RPL estimates.<sup>28</sup> As shown by the marginally significant and positive estimates ( $\Delta_{H-E}$ ), hierarchists, all other things being equal, are willing to pay \$0.179 higher for products produced with the genetic modification technology, and \$0.12 for the edible coating method, compared with egalitarians. Also, consumers holding relatively individualistic worldviews are shown as willing to pay less for each novel technology than the communitarians. Compared to communitarians, individualists are willing to pay \$0.212, \$0.596, and \$0.61 less for gene editing, genetic modification, and edible coating technology, respectively.

These findings also partially support H<sub>2</sub>. A hierarchical worldview disposes individuals to react more favourably towards food technologies, because the stratified social orderings are important, and supporting the authorities of social elites such as scientists and regulators conforms to hierarchical worldview. As a result, hierarchists are more likely than egalitarians to hold a more positive attitude and are willing to pay higher values for novel food technologies. However, contrary to H<sub>2</sub>, an individualistic worldview disposes individuals to react more negatively towards food technologies. Individualists, who believe individual interests are more important than collective social welfare, may fail to perceive individual-level benefits of the food technologies included in study. As such, they are less likely than communitarians to hold positive attitudes and higher WTP values for food technologies.

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<sup>28</sup> In order to test the significance of differences in mean WTP values between cultural groups, I also run a regression in which individuals' WTP values are the dependent variable, while dummy variable 'Hierarchist' or 'Individualist' and a constant term are independent variables. For example,  $WTP_{GE\_n} = Intercept + \beta \times 'Hierarchist'_{-n} + \varepsilon$  and  $WTP_{GE\_n} = Intercept + \beta \times 'Individualist'_{-n} + \varepsilon$ . Results show that estimates associated with 'Hierarchist' or 'Individualist' are statistically significant at the 1% level for all three novel technologies. That is, being 'Hierarchist' or 'Individualist' has significant impacts on the WTP values for food technologies.

### 3.7 Conclusion

Biotechnology has offered scientists a versatile tool to control the genetic material of plants with a higher degree of precision, speed, and control, compared to conventional production methods. The resulting crops can exhibit diverse characteristics, such as resistance to pests and herbicides, tolerance to extreme growing conditions, and offer benefits to consumers through enhanced nutritional content. However, public views on biotechnology are not uniformly positive. One prominent example of biotechnology, known as genetic modification, has received persistent opposition among segments of the public (Costa-Font, Gil and Traill 2008; Hu et al. 2004; Hu, Veeman and Adamowicz 2005; Lusk et al. 2005; Lusk, Roosen and Fox 2003). Previous studies suggest that aversion by some members of the public may result from their lack of knowledge on biotechnology House et al. (2004) and lack of trust in the institutions regulating the technology (Siegrist 2008). A number of efforts made by psychologists and economists further suggest that public perceptions and attitudes are shaped by a set of psychosocial factors, such as cognitive biases, emotions, moral considerations, and even worldviews.

Effects of cultural worldviews on technology assessment has received rising attention among scholars. The theory of cultural cognition indicates that individuals tend to conform their beliefs about disputed matters to their cultural values (Kahan 2012), and significant cultural value effects have been identified in controversial societal matters such as nanotechnology (Kahan et al. 2009), climate change (Kahan, Jenkins-Smith and Braman 2011), handgun use (Kahan et al. 2007), and vaccination (Kahan et al. 2010). As posited by cultural cognition theory, a hierarchical worldview tends to dispose people to hold more positive and favorable attitudes towards technological advances, as hierarchists value the authority of social elites (e.g., scientists, governmental authorities) and acknowledging technological risks would threaten the social orderings they support. Also, a relatively individualistic worldview tends to dispose people to perceive greater benefits of novel technologies as they are more concerned about whether individual interests and market autonomy are secured. By contrast, people holding egalitarian and communitarian worldviews are more likely to react negatively towards novel technologies as they are more concerned about the potential inequality and social harms resulting from the unregulated scientific activities.

To my knowledge, however, very few studies have examined cultural effects in a food domain. Also, economic studies often underestimate or completely omit impacts of human values. This study aims to fill the knowledge gap by providing a nuanced understanding of the role of cultural values in shaping attitudes and behaviours related to novel food technologies.

Two testable hypotheses are developed based on the theory of cultural cognition. First, it is assumed that individuals holding relatively hierarchical and/or individualistic cultural worldviews are more likely to perceive the benefits of food technology as predominating its risks, and thus they are more likely to support food technology, compared with individuals holding egalitarian and/or communitarian worldviews ( $H_1$ ). Second, it is expected that individuals holding relatively hierarchical and/or individualistic cultural worldviews are more likely to purchase and are willing to pay a greater values for foods produced with novel food technology, compared with individuals holding egalitarian and/or communitarian worldviews ( $H_2$ ). Additionally, compared with genetic modification, gene editing technology that does not necessarily introduce foreign genes into plants is assumed to be perceived more favourably and thus is more preferred by consumers ( $H_3$ ).

To test these hypotheses, consumer data were collected from an online survey conducted in the summer of 2016 on 804 Canadian adults. Data were collected on respondents' cultural worldviews (i.e., cultural value scales developed by Kahan (2012) – Hierarchy-Egalitarianism (*HE*) and Individualism-Communitarianism (*IC*)), perceptions of novel food technologies, and food choice behaviours. In particular, a choice experiment was included in the online survey to elicit preferences for diverse consumer-oriented apple benefits (non-browning, antioxidant-enhanced) and novel food technologies (gene editing, genetic modification, edible coating). A set of analyses were conducted including descriptive analysis, multivariate regression analysis, and choice modelling analysis.

Descriptive results show that the sampled population hold relatively positive views on science and technology in general, however, when it comes to food biotechnology in particular, the majority report low familiarity levels and low preferences. Respondents were asked to report their beliefs about the naturalness, ethics, and safety of five different food production methods, including crossbreeding, mutagenesis, gene editing, genetic modification, and edible coating. Among them, conventional crossbreeding was perceived as being the most natural, ethical and safe method; while mutagenesis by chemicals or radiation were believed as the least natural, ethical and safe

production method. When comparing the two biotechnologies, gene editing which makes changes to a plant's existing genes, was perceived as being more natural, ethical, and safer than genetic modification which often involves inserting foreign genes from other species into plants (H<sub>3</sub> is supported). A similar perception pattern was also identified in the choice data analysis.

Results of both choice models, MNL and RPL, reveal that all three novel food technologies – two plant breeding techniques gene editing and genetic modification, and one food processing method edible coating – are associated with negative marginal utilities and WTP values (i.e., an implicit WTP to avoid novel technologies). That is, compared with the conventional production method, all novel food technologies are discounted by respondents.

However, a closer look at the model results further indicates that respondents discount gene editing technology significantly less than genetic modification and edible coating, *ceteris paribus*. Such a finding confirms H<sub>3</sub>, and also has significant implications for the food industry and regulators. As gene editing and genetic modification are perceived and evaluated differently, informing consumers about how gene edited and genetically modified foods differ could be a key strategy to reduce the opposition towards gene editing, which would otherwise receive similar aversion as has been the case with genetic modification.

Such a comparison between different food technologies also has important implications for the development of regulatory policy governing new food technologies. Genetic modification often involves inserting genes from other species into the plants, while the gene editing technology can make changes to existing plant genes without introducing any foreign genes from other species. Under current regulatory regimes, genetically modified crops are subject to extensive regulatory evaluation in both Canada and the U.S., and the regulatory environment is even stricter in the European Union (EU). With respect to gene editing technology, the EU has not published its regulatory strategy for gene-edited crops, for example, whether to regulate gene editing in the same way as genetic modification. In the U.S., a gene-edited mushroom that resists browning has recently bypassed the U.S. Department of Agriculture (USDA) regulations for genetically engineered organisms since it does not contain any foreign genetic material inserted into the mushroom genome (Waltz 2016). As such, results suggest that these two biotechnology methods may be regulated under different regimes as they are perceived by consumers as distinct from each other.



The consumer-oriented apple characteristics introduced by food technologies are shown to be welcomed by respondents. Both models suggest that the non-browning and antioxidant-enhanced attributes in prepackaged sliced apple products are associated with significant and positive marginal utilities and WTP values, even though strong evidence shows that preference heterogeneity among consumers appears to exist.

More importantly, this study identified significant cultural values effects in shaping attitudes and behaviours related to food technologies. Results of multivariate regression suggest that, *ceteris paribus*, a hierarchical worldview disposes sampled respondents to be supportive for gene editing, while individualistic worldview disposes people to hold (*insignificantly*) more negative attitudes towards gene editing. That is, H<sub>1</sub> is only partially supported by the results. Similar cultural value effects are also identified in choice analysis. Both choice models suggest that people holding a relatively hierarchical worldview are more likely to buy and pay higher WTP values for food technologies, compared with people holding an egalitarian worldview. On the other hand, people holding a relatively individualistic worldview are more likely to show weaker preferences and lower WTP values for food technologies, as opposed to people holding a communitarian worldview.

Both hypotheses (H<sub>1</sub> and H<sub>2</sub>) are only partially verified by data, a possible explanation is that hierarchists are disposed to hold favorable attitudes towards novel technology as acknowledging its risks could threaten the competence of social and governmental elites, such as scientists and regulators, as such H<sub>1</sub> and H<sub>2</sub> are supported. As posited in cultural cognition theory, people holding individualistic worldviews believe individual interests are more important than collective social welfare, however, they fail to perceive gene editing as offering substantial benefits at the individual level (i.e., providing tangible and direct benefits to consumers). This is somehow consistent with the fact that biotechnology has been mostly targeted at farmers (e.g., developing crops with greater productivity or resistance to diseases and pests) and applied in processed food ingredients that consumers can hardly observe. Hence, individualists are less likely to support gene editing and are more likely to exhibit weaker preferences and lower WTP values for food technologies. By contrast, communitarians tend to perceive greater collective benefits of novel food technologies to the society as a whole. As such, H<sub>1</sub> and H<sub>2</sub> are violated.

These explanations are worth further investigation, however, they still offer significant insights. As stated earlier, very few studies have extensively explore effects of cultural worldviews on food technology perceptions and choices. The findings suggest that impacts of cultural values may vary depending on research contexts. Influences of cultural values on perceptions and behaviours in the food domain could dramatically differ with those in other contexts, such as nanotechnology, climate change, handgun use and vaccination (Kahan et al. 2007; Kahan et al. 2009; Kahan et al. 2010; Kahan, Jenkins-Smith and Braman 2011). Different societal disputed matters require separate investigations of cultural value impacts, potentially due to the specific nature of the matter. For instance, nanotechnology is perceived more favourably by individualists than by communitarians (Kahan et al. 2009), potentially because it is perceived by the public as having great potentials to provide individual benefits (e.g., stain-resistant clothing, faster and smaller computers, more effective skincare products, and better disease treatments). By contrast, gene editing is less likely to be supported by individualists potentially because it is believed by the public as providing little tangible and direct benefits to individual consumers. Therefore, cultural worldviews may exert different influences on different (food) technologies or even different applications of the same technology as they possess differing characteristics.

Further, to counteract the cultural value effects (or biases), value-compatible messages may help in the public communication of a disputed matter. For instance, to facilitate the discussion of gene editing with people holding relatively individualistic worldview, who are disposed to oppose the technology due to cultural value effects, the potentials of gene editing to provide tangible individual benefits (e.g., foods with higher nutritional values or convenience for consumption) should be emphasized; while the potentials of nanotechnology to promote overall social welfare (e.g., environmental clean-up, national security enhancement) need to be emphasized when communicating with people holding communitarian worldviews, who are disposed to oppose nanotechnology.

Cultural values were measured in this study with a two dimensional continuous cultural cognition scale developed by Dan Kahan (Kahan et al. 2007; Kahan et al. 2009; Kahan 2012). The cultural cognition scales are originally rooted in U.S. culture and developed in an English-speaking context. Hence, their reliability has to be assessed when applied to historical and cultural contexts that are distinct from the U.S.

A few attempts have been made when applying Kahan's cultural cognition survey questions in a Canadian context, the reliability of scales is revealed, however, to be mixed. For example, in a study of public opinion on Biofuels, Dragojlovic and Einsiedel (2014) showed their slightly modified versions of cultural cognition items load appropriately on two factors and exhibit adequate reliability. However, Lachapelle, Montpetit and Gauvin (2014) and Perrella and Kiss (2015) revealed that the two dimensional cultural scales are relatively unsatisfactory in reliability, instead three or four distinct cultural dimensions fit better with their samples from Quebec and Waterloo (Ontario), respectively.

The mixed results of reliability in a Canadian context may stem from the fact that Canada is a bilingual and multicultural society and has different political party systems.<sup>29</sup> Hence, more than two discrete worldviews may exist and should be measured. In addition, the subject matters of items designed to measure attitudes on equality, minority rights, gender roles, and the role of government, and racial stratification may be more fundamental in U.S. society but rather less relevant to a Canadian context. As a result, more work is required to develop reliable cultural scales that can measure worldviews rooted in the Canadian cultural context for both English and French speaking communities. An example of such efforts was made by Montpetit et al. (2017).

Another limitation of this study is associated with the hypothetical nature of the survey. As a means to incentivize participation, respondents had a chance to win one of two prizes of \$500 once they completed survey questionnaires. However, since the monetary compensation was not linked with individuals' responses, the stated preference survey is still subject to a potential hypothetical bias. As such, we should be cautious when interpreting results obtained in this study, especially willingness-to-pay values, as they do not necessarily translate into the real behaviours or monetary values when the hypothetical novel products become available in the market. Future studies may use revealed preference experimental auctions or real economic incentives to assess consumers' preferences and willingness-to-pay for new food products.

Furthermore, the choice experiment uses sliced apples as the product of interest. The prepackaged apple slices are non-browning or antioxidant-enhanced by novel food technologies. Individuals'

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<sup>29</sup> As shown in Appendix 3.II, this study identified significant cultural worldview differences between respondents from Quebec and the rest of Canada, however, these differences do not appear to affect perceptions and choice behaviours related to food technologies.

preferences and valuations for novel food traits and/or technologies may differ as the products change. For example, it is possible that apples have already been symbolized as healthy fruits by offering greater amounts of dietary antioxidants like Vitamin C, hence boosting the level of antioxidant is less important or valuable for apples. However, individuals could become more enthusiastic if higher level of antioxidants by novel food technologies are present in products perceived as less healthy, such as beverages. Attitudes towards the same food technology could be very different depending on its application, the context, and the benefits offered. Thus, future research could extend to understand whether public perceptions change when gene editing is applied to other food categories (e.g., meat or dairy products) and offering different benefits (e.g., improved animal welfare or beneficial environmental impacts).

The current study provides a ‘snapshot’ view of public perceptions of novel food technologies, however, a future longitudinal study would be required to understand the dynamics of attitude and acceptability of novel food technologies. As consumers become more aware of novel technology applications and their benefits and risks through mass media or social media networks, their attitudes could change over time. Hence, future research using consumer panel data could provide insights into the evolution of public perceptions.

In sum, this study contributes to existing literature on consumers’ attitudes towards novel food technologies by providing a more nuanced understanding of the effects of cultural worldviews. As results revealed significant cultural value effects, further research should consider incorporating these underlying human values when exploring new food technology perceptions and behaviours.

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### Appendix 3.I – Factor Analysis of Cultural Worldview Scales

To measure respondents' cultural worldviews, Kahan's twelve-question cultural cognition scales were used in this study. Factor analysis is conducted to evaluate the reliability of these scales, and the results are presented in this appendix.

In the survey, each respondent was asked to indicate his/her level of agreement or disagreement to the twelve items on a 6-point scale (Table 3.A1). Items prefixed with the letters 'E' and 'C' are reverse coded such that a higher score on items in 'Hierarchy-Egalitarianism' ('Individualism-Communitarianism') suggests a relatively more hierarchical (individualistic) worldview.

**Table 3.A1 Cultural Worldview Items**

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All items have a six-point response scale: 1=Strongly Disagree, 2=Moderately Disagree, 3=Slightly Disagree, 4=Slightly Agree, 5 Moderately Agree, 6=Strongly Agree.

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#### *Hierarchy-Egalitarianism*

- H\_1 We have gone too far in pushing equal rights in this country.
- H\_2 Society as a whole has become too soft and feminine.
- H\_3 It seems like groups of people such as ethnic minorities, women, homosexuals, and other groups don't want equal rights, they want special rights just for them.
- E\_1 Discrimination against minorities is still a very serious problem in our society.
- E\_2 We need to dramatically reduce inequalities between different groups, such as the rich and the poor, whites and visible minorities, and men and women.
- E\_3 Our society would be better off if the distribution of wealth was more equal.

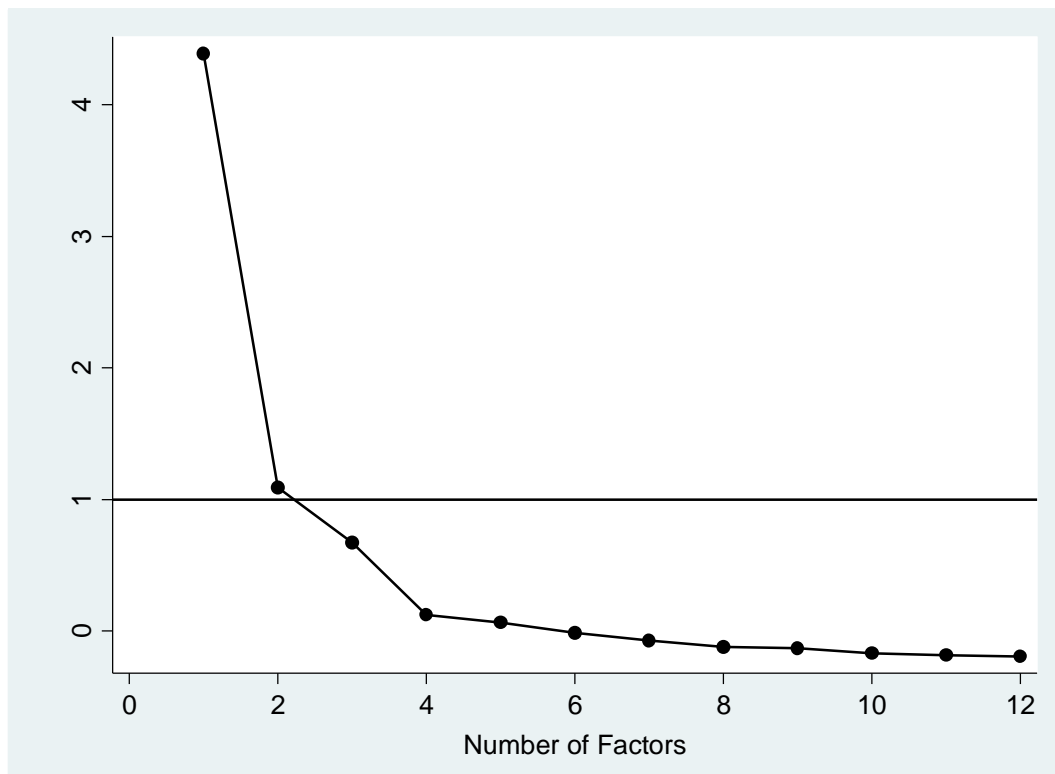
#### *Individualism-Communitarianism*

- I\_1 The government interferes far too much in our everyday lives.
  - I\_2 The government should stop telling people how to live their lives.
  - I\_3 It's not the government's business to try to protect people from themselves.
  - C\_1 Sometimes government needs to make laws that keep people from hurting themselves.
  - C\_2 Government should put limits on the choices individuals can make so they don't get in the way of what's good for society.
  - C\_3 The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals.
- 

Source: Kahan (2012).

Since the cultural cognition scales are designed to characterize worldviews on two cross-cutting dimensions, it is expected that the items load accordingly on two latent factors. There are a number of criteria to help determine how many factors to retain. First, the Kaiser Criterion rule suggests

to retain the number of factors with eigenvalues greater than 1, since only factors that explain at least as much variance as a single variable are worth keeping (Jackson 1993). This suggests that two factors fit the data set. Second, the number of factors to generate is indicated by the ‘elbow’ of scree plot, which shows eigenvalues on the y-axis and number of factors on the x-axis (Jackson 1993). This rule also suggests two latent factors would fit the data (Figure 3.A1).



**Figure 3.A1 Scree plot of eigenvalues**

The main purpose of factor analysis is to identify a smaller number of interpretable latent factors that can explain the maximum amount of variability in observed data. Thus a third rule is to look at the total amount of original variability in observed variables explained by latent factors. The results of factor analysis constraining 12 items to load on 2 factors are presented in Table 3.A2. The results suggest that a 2-factor model can explain 46% of the variance in observed responses to 12 items.

**Table 3.A2 Factor Loadings of 12 Cultural Worldview Items on 2 Latent Factors**

Variable	Factor 1 <sup>a</sup>	Factor 2
H_1	<b>0.761<sup>b</sup></b>	0.180
H_2	<b>0.676</b>	0.199
H_3	<b>0.742</b>	0.215
E_1	<b>0.599</b>	0.135
E_2	<b>0.671</b>	0.177
E_3	<b>0.582</b>	0.230
I_1	0.414	<b>0.589</b>
I_2	0.284	<b>0.647</b>
I_3	0.277	<b>0.598</b>
C_1	0.247	<b>0.514</b>
C_2	0.045	<b>0.579</b>
C_3	0.142	<b>0.626</b>
Proportion Variance	0.262	0.195
Cumulative Variance	0.262	0.457

Note: Number of observations = 1407 (n=697 in ‘Bio’ survey and n=710 in ‘Nano’ survey).

<sup>a</sup> Results of factor loadings are obtained after orthogonal varimax rotation.

<sup>b</sup> Factor loadings greater than 0.5 or less than -0.5 are shown in bold.

Finally, it is also important to examine whether the extracted factors and their loading patterns make any theoretical sense. To meet the interpretability criteria, a rule-of-thumb is that each factor should have at least three variables with high factor loadings, and each variable should load highly on only one factor. The factor loadings presented in Table 3.A2 suggest that the 12 items load appropriately on two latent factors. All the H- and E- items load highly on the first factor, and the I- and C- items load strongly on the second factor, given the orthogonality of two latent factors.

The loading patterns are consistent with the initial conceptualization of cultural cognition scales, and similar loading patterns have also been identified in Dragojlovic and Einsiedel (2014) and demonstrated in Montpetit et al. (2017), who applied the same cultural cognition scale to Canadian adults in an opinion polling.

Individual HE and IC scores could be extracted from the factor loadings using the regression method. However, as the loading values for each item are not very different, I compute HE and IC score by averaging items for each scale. Actually, I find the two methods – regression-based factor scores vs. average scores – would generate similar estimation results.

### Appendix 3.II – Difference in Cultural Worldviews between Quebec and the rest of Canada

As Canada is a bilingual and multicultural society, it is interesting to investigate if difference in cultural worldviews exists between people residing in Quebec and the rest of Canada. Similar difference may also exist between people speaking French and English. As such, this section compares cultural worldviews across different locations and languages.

Among the 697 respondents completed 'Bio' survey, 155 (22%) reside in Quebec, and a majority of them (128) chose to finish the survey in French (Table 3.A3). The remaining 542 respondents reside outside of Quebec, and only 2 of them completed survey in French. Most French surveys are completed by respondents residing in Quebec. It is expected that Quebec residents may differ with the rest of Canadians in cultural worldviews as a result of their different linguistic, cultural, and social background.

**Table 3.A3 Number of Surveys Completed in Quebec and French**

	Quebec	Rest of Canada	Total
French	128	2	130
English	27	540	567
Total	155	542	697

Table 3.A4 compares the mean cultural worldview scores for residents of Quebec and the rest of Canada. Results of two-sample *t* tests indicate that Quebec residents are relatively less hierarchical (at 1% significance level) and less individualistic (at 10% significance level) than people residing outside Quebec. As such, there exists difference in cultural worldviews between people from Quebec and the rest of Canada.

**Table 3.A4 Cultural Worldviews by Location**

	Quebec	Rest of Canada	Average
Hierarchy-Egalitarianism (HE)	2.41 (0.96) ***	2.69 (1.24)	2.63 (1.19)
Individualism-Communitarianism (IC)	3.52 (0.97) *	3.70 (1.03)	3.66 (1.02)

Notes: a. Standard deviations in parentheses.

b. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

Taking this location (Quebec vs. rest of Canada) difference into account, a multinomial logit (MNL) model with additional interaction effects is estimated (see Table 3.A5).



**Table 3.A5 MNL models Considering Quebec/Rest of Canada Difference**

	<b>MNL 1 (Table 3.4)</b>		<b>MNL 2</b>	
<b>Mean</b>	Estimate	Std. Err.	Estimate	Std. Err.
NB	0.694***	0.070	0.692***	0.070
AE	0.158**	0.065	0.158**	0.065
GE	-1.127***	0.195	-1.147***	0.197
GM	-1.074***	0.218	-1.081***	0.219
EC	-0.997***	0.209	-1.055***	0.211
PRI	-0.658***	0.038	-0.657***	0.038
No-purchase	-3.375***	0.167	-3.374***	0.167
<b>Mean Shifter</b>				
GE×HE	0.121***	0.045	0.127**	0.050
GE×IC	-0.047	0.053	-0.054	0.057
GM×HE	0.244***	0.053	0.262***	0.059
GM×IC	-0.290***	0.062	-0.307***	0.067
EC×HE	0.149***	0.050	0.136**	0.056
EC×IC	-0.210***	0.058	-0.203***	0.063
GE×HE×Quebec			0.005	0.116
GE×IC×Quebec			0.037	0.084
GM×HE×Quebec			-0.067	0.136
GM×IC×Quebec			0.078	0.101
EC×HE×Quebec			0.119	0.123
EC×IC×Quebec			-0.000	0.091
<b>Model Fit</b>				
Log likelihood	-5359.4		-5355.1	
AIC/N	2.569		2.570	
BIC/N	2.589		2.599	
Pseudo R <sup>2</sup>	0.076		0.076	
No. of Parameters	13		19	

Notes: 1. Number of respondents = 697.

2. Number of choices observed = 4182.

3. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

Cultural value effects on food technology perceptions are examined by interacting the cultural worldview scores (*HE* and *IC*) with food technology attributes (*GE*, *GM*, and *EC*) (see MNL 1).

As cultural worldviews held by people from Quebec are found to be statistically different with

people from the rest of Canada, MNL 2 investigates whether cultural value effects on food technology perceptions are also different across locations. As such, six additional 3-level interactions are added by interacting the location variable (i.e., *Quebec*, a dummy variable takes value of 1 if the respondent resides in Quebec when completed survey) with the variables capturing cultural value effects on food technology perceptions (i.e.,  $GE \times HE$ ,  $GE \times IC$ ,  $GM \times HE$ ,  $GM \times IC$ ,  $EC \times HE$ ,  $EC \times IC$ ).

A comparison between the two MNL models indicates that six additional interaction effects are jointly *insignificant*, as the log-likelihood values do not change significantly (likelihood ratio test, i.e.,  $LRT=8.647 < \chi^2_{0.01}(6)=16.812$ ). That is, considering the location difference in cultural value effects on food technology perceptions does not provide additional insights into understanding choice behaviours related to food technologies. Particularly, MNL 2 also reveal that none of these 3-level interaction effects are individually significant. Therefore, I conclude that people residing in Quebec are relatively less hierarchical and individualistic than people living outside Quebec, however, such location difference in cultural worldviews does not have significant impacts on the relationship between cultural values and preferences for novel food technologies.

### Appendix 3.III Choice Model Results with Additional Interaction Terms

The primary analysis shown in Table 3.4 examines cultural value impacts on preferences for three food technologies by interacting three technologies (*GE*, *GM*, *EC*) with cultural worldviews (*HE*, *IC*). To investigate if cultural worldviews also have impacts on preferences for the other two novel food attributes – non-browning (*NB*) and antioxidant-enhanced (*AE*) – I also run MNL and RPL models with interaction terms between the two apple attributes (*NB*, *AE*) and cultural worldviews (*HE*, *IC*). Estimation results with additional interaction terms are presented in Table 3.A6.

**Table 3.A6 Choice Model Results with Additional Interaction Terms**

	MNL		RPL	
			<i>Random Parameters</i>	
<b>Mean</b>	Estimate	Std. Err.	Estimate	Std. Err.
NB	0.864***	0.262	1.628**	0.688
AE	0.104	0.244	0.327	0.621
GE	-1.216***	0.342	-1.861*	1.014
GM	-1.173***	0.363	-1.803*	0.980
EC	-1.094***	0.359	-1.411	1.081
PRI	-0.658***	0.038	-1.741***	0.082
			<i>Non-random Parameters</i>	
No-purchase	-3.378***	0.167	-9.948***	0.467
<b>Mean Shifter</b>				
NB×HE	0.076	0.067	0.206	0.168
NB×IC	-0.103	0.079	-0.220	0.196
AE×HE	0.001	0.063	0.051	0.163
AE×IC	0.014	0.074	-0.047	0.186
GE×HE	0.066	0.088	0.297	0.253
GE×IC	0.018	0.103	-0.138	0.294
GM×HE	0.185**	0.094	0.569**	0.259
GM×IC	-0.219**	0.110	-0.616**	0.291
EC×HE	0.090	0.093	0.445	0.279
EC×IC	-0.139	0.108	-0.626*	0.326
<b>Standard Deviation</b>				
$\sigma_{NB}$			2.291***	0.193
$\sigma_{AE}$			2.084***	0.178
$\sigma_{GE}$			1.520***	0.222
$\sigma_{GM}$			0.867***	0.331

$\sigma_{EC}$		2.312***	0.222
$\sigma_{PRI}$		1.741***	0.082
<b>Error Components</b>			
$\theta_{novel}$		1.724***	0.408
$\theta_{conventional}$		3.518***	0.305
$\theta_{no-purchase}$		4.999***	0.428
<b>Model Fit</b>			
Log likelihood	-5358.0		-3575.7
AIC/N	2.571		1.722
BIC/N	2.596		1.760
Pseudo R <sup>2</sup>	0.076		0.383
No. of Parameters	17		26

Notes: 1. Number of respondents = 697.

2. Number of choices observed = 4182.

3. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

Table 3.A6 investigates impacts of cultural worldviews (*HE, IC*) on all novel food attributes (*NB, AE, GE, GM, EC*). Models shown in Table 3.4 differ with that in Table 3.A6, which considers potential effects of cultural worldviews on two additional apple characteristics (*NB, AE*). A comparison between Table 3.4 and Table 3.A6, however, indicates that including additional interaction terms does not significantly improve the model fit. For the MNL models, log-likelihood value changes from -5359.4 to -5358.0 with additional interactions, and the values of Pseudo R<sup>2</sup>, AIC, and BIC do not change significantly. Adding more interaction terms reduce the model fits for RPL models (values of log-likelihood and Pseudo R<sup>2</sup> both decrease). Thus, I conclude that these additional interaction terms between apple characteristics (*NB, AE*) and cultural worldviews (*HE, IC*) are jointly *insignificant*.

Additionally, all interaction terms between the two apple attributes (*NB, AE*) and cultural worldviews (*HE, IC*) are statistically *insignificant* in both the MNL and RPL models. Hence, results suggest that cultural worldviews may not have significant impacts on preferences for these two novel apple attributes. For this reason, Table 3.4 presents results with interaction terms between only the three food technologies (*GE, GM, EC*) and cultural worldviews (*HE, IC*).

## **Chapter 4 – Food Values and Appraisal of Novel Food Technologies**

### **4.1 Introduction**

Plants and food products with desirable traits are developed using novel food technologies, however, consumer acceptance of new products varies depending on specific benefits offered as well as the particular techniques used to achieve those traits. For example, studies suggest that consumers view food nanotechnology, which deals with things at extremely small scales, more favourably in comparison to food biotechnology (Cobb and Macoubrie 2004; Giles et al. 2015; Parisi, Vigani and Rodriguez-Cerezo 2015; Yue, Zhao and Kuzma 2015; Yue et al. 2015). Research on applications of nanotechnology in food and agriculture, however, is still at early stage and consumers have very limited knowledge about it. Thus, the tacit acceptance of nanotechnology may change, either positively or negatively as consumers are exposed to more information and become more familiar with the technology (Besley 2010; Scheufele and Lewenstein 2005).

Attitudes towards new food technologies may not be static and can evolve over time, however, there may exist factors that are more stable and deep-seated in consumers' minds, which can motivate technology acceptance. For example, people's preference for non-genetically modified (non-GM) over GM foods is not stable as it may reverse over time, however, the values or the end-states of existence (i.e., consequences) resulting from eating non-GM instead of GM (e.g., satisfaction with eating 'natural' food products, and avoidance of 'novel' or unfamiliar foods) are relatively more stable. The relative importance of these values or end-states of existence may differ across individuals and over time, hence, people are holding different attitudes and their attitudes may also change over time.

This chapter aims to provide a better understanding of the values or end-states of existence that are associated with food consumption, particularly, how these food values may shape attitudes and influence choice behaviours related to food nanotechnology. Eleven food values are identified by Lusk and Briggeman (2009), including naturalness, taste, price, safety, convenience, nutrition, tradition, origin, fairness, appearance, and environmental impact. This list of food values represents a reasonably comprehensive set of abstract and stable values or end-states of existence related to food consumption. Also, food values have been shown to have considerable power in explaining a variety of food-related behaviours, such as actual purchasing behaviour of organic

eggs and milk (Lusk 2011), preferences for specific animal food products (Lister et al. 2017), and dietary acculturation of international university students (Tirelli, Martinez-Ruiz and Gomez-Ladron-De-Guevara 2013). To the best of my knowledge, however, there exists no study examining the impacts of food values on attitudes and choice behaviours related to food nanotechnology within a Canadian context.

Nanotechnology is the technological advance that involves characterizing, fabricating, and manipulating matter at approximately 1-100 nanometers length scale (one nanometer is a billionth of a meter, i.e., 1 nanometer= $10^{-9}$  meters), at which the physical and chemical properties of materials are significantly differed from those at a larger scale (Duncan 2011; National Nanotechnology Initiative 2017). Nanotechnology could be applied in agri-food sectors such as agricultural production, nutrient supplements, food processing, and food packaging (Handford et al. 2014). Examples of nanotechnology in food applications are the potential to develop food fortified with nano-sized nutrients, and intelligent food packaging with nano-sensors that indicate the freshness of the food product inside the package (Duncan 2011; Ravichandran 2010).

Studies suggest that public knowledge of food nanotechnology is quite limited, however, consumer attitudes are currently neutral or slightly positive in general (Cobb and Macoubrie 2004; Cook and Fairweather 2007; Currall et al. 2006; Frewer et al. 2014). Nanotechnology is more likely to be accepted by consumers if it delivers more tangible and concrete consumer benefits. In particular, nanotechnology is more acceptable when it is applied to food packaging or processing, compared to when it is directly used in foods (Bieberstein et al. 2013; Siegrist et al. 2007; Siegrist et al. 2008; Stampfli, Siegrist and Kastenholtz 2010).

Some efforts have been made to understand the determinants of consumer acceptance of food nanotechnology. It is found that certain population groups (e.g., whites, males, and more educated individuals) are more accepting of food nanotechnology than others (Casolani et al. 2015; Cobb and Macoubrie 2004; Conti, Satterfield and Harthorn 2011; Siegrist et al. 2008). Acceptance of food nanotechnology is also found to be affected by psychosocial factors, such as an individual's views on nature and science in general (Stampfli, Siegrist and Kastenholtz 2010; Vandermoere et al. 2010; Vandermoere et al. 2011), importance of 'naturalness' to their food purchases (Siegrist, Stampfli and Kastenholtz 2009), level of food neophobia (i.e., reluctance to eat, or avoidance of, new and unfamiliar foods) (Schnettler, Crisóstomo, Mills, et al. 2013; Schnettler, Crisóstomo,

Sepúlveda, et al. 2013; Schnettler et al. 2014), and trust and confidence in the food industry and regulation (Roosen et al. 2015; Siegrist et al. 2007; Siegrist et al. 2008; Stampfli, Siegrist and Kastenholz 2010). Additionally, different types and sequence of information (e.g., environmental, societal, and health information) about nanotechnology are shown to have differing impacts on consumers' willingness-to-pay for foods produced using nanotechnology (Marette et al. 2009; Roosen et al. 2011). None of these studies, however, consider the impacts of deep-seated food-related human values on the acceptance of food nanotechnology.

This study fills a knowledge gap by, first, examining whether consumers' attitudes towards food nanotechnology are an expression of their stable underlying food-related values, i.e., an alternative set of psychometric constructs. Values deep-seated in an individual's psyche are more central and stable constructs that help explain attitudes and preferences. Knowledge and research regarding consumer acceptance or rejection of food nanotechnology is limited, and consumer attitudes are subject to change depending on further information exposure. Thus, studies in understanding the psychosocial or cultural factors which may influence consumer responses to food nanotechnology are still needed (Giles et al. 2015). This chapter explores determinants of food nanotechnology acceptance that are more stable and deep-rooted in peoples' minds – food values – which are a set of psychometric constructs that may have significant power in explaining and predicting consumer responses to food nanotechnology.

To the best of my knowledge, no studies have used a comprehensive list of food values developed by Lusk and Briggeman (2009) to understand acceptance of food nanotechnology. A number of studies, however, have examined the impacts of either one particular or a subset of food values on a wide range of alternative topics, although some of these studies did not explicitly use the term 'food values'. For example, perceived 'naturalness' has been found as an important factor that affects food choice (Rozin et al. 2004; Rozin 2006) or acceptance of genetically modified food (Tenbult et al. 2005). Perceived levels of 'taste', 'safety', as well as labelling of 'origin' are shown to have significant influences on demand for meat products (Loureiro and Umberger 2007; Malone and Lusk 2017). Also, concern about 'fairness' (distribution of benefits across the food supply chain resulting from food purchase) is found to be a significant factor explaining the preference for organic food (Chang and Lusk 2009).

It is also noteworthy that these studies coincidentally use some of the ‘food value’ item(s), however, they did explicitly set out to measure stable underlying and deep-rooted food-related human values. Most of these studies used ‘food value’ item(s) to describe specific food attributes in question. However, as stated by Lusk and Briggeman (2009), the “food values” scale was developed to reflect the “end states” (i.e., outcomes) of food purchase or consumption. As such, the scale is meant to capture more *abstract* human values, rather than *concrete* food attributes. A comprehensive but slightly adapted list of food values is used in this chapter to understand the impacts of deep-seated food related human values on consumer acceptance of nanotechnology applied to food production. In particular, this study explores how these underlying food values may have influences on people's evaluations of specific food characteristics obtained by means of nanotechnology.

Second, by capturing food choice behaviours in an experiment, this study investigates if consumer-oriented benefits (i.e., apple slices that are resistant to browning and enhanced with dietary antioxidants like Vitamin C) obtained by means of food nanotechnology (i.e., nano-coating) are perceived as acceptable by consumers, particularly, by which types of consumers. Consumers are expected to be heterogeneous in their food values and preferences for novel food characteristics and nanotechnology. As such, this study estimates a set of choice models, including a random parameter logit (RPL) model and a latent class model (LCM). Both models allow for incorporating psychometric measures (i.e., food values) into explaining choice behaviours. In particular, estimating a LCM in this study helps reveal additional dimensions of preference heterogeneity among consumers. The LCM identified three consumer segments – supporters, doubters, and opponents – who differ in their acceptance of food nanotechnology and the food values they perceive as important.

The remainder of this chapter is organized as follows. Section 4.2 summarizes both theoretical and empirical studies on human values and especially food values, based on which a set of hypotheses are developed in section 4.3. Data on consumers’ food values and their food choices are collected from an extensive online survey conducted across Canada. Section 4.4 describes the survey design and section 4.5 specifies the models used for choice data analysis. In this study, food values are found to have significant power in explaining preferences for novel food attributes and nanotechnology, section 4.6 presents and discusses the empirical results and section 4.7 concludes.



## 4.2 Food Values

Attitudes towards new food technologies may be ill-defined as consumers have very little information and knowledge to help them form attitudes or preferences. Also, food technology perceptions are very likely to change over time when consumers become more knowledgeable about the technology. This study aims to understand the effects of an alternative psychometric construct, i.e., the underlying and deep-rooted human values that specifically relate to food consumption, on individuals' assessments of novel food technologies. Values deep-rooted in an individual's psyche may be more central and stable than attitudes or preferences, and hence help explain how food technology attitudes and preferences form and change over time.

A human value is defined by Rokeach (1973, p.5) as “an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence”, and a value system is the “enduring organization of beliefs concerning preferable modes of conduct or end-states of existence along a continuum of relative importance”. More importantly, “the consequences of human values will be manifested in virtually all phenomena that social scientists might consider worth investigating and understanding” (Rokeach 1973, p.3).

Human values are said to be more central and stable than preferences and they are therefore determinants of behaviours, attitudes, judgments, etc. (Rokeach 1973).<sup>30</sup> That is, preferences, attitudes and behaviours express underlying values. For example, while an individual's preference for non-GM over GM foods might be unstable over time, the values or the end-states of existence resulting from eating non-GM instead of GM (e.g., satisfaction from consuming food that is perceived as more ‘natural’ and avoiding unfamiliar food ingredients) are relatively more stable, and thus guide their choice behaviours.

Efforts have been made to develop comprehensive and culturally universal sets of human values. Rokeach (1968; 1973) constructed two reasonably comprehensive lists of human values, including 18 terminal values (i.e., preferable end-states of existence), such as “a comfortable life”, “a world

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<sup>30</sup> Even though human values and a value system could be more stable than attitudes or preferences, they are not completely stable. The relative importance of human values may evolve as a result of changes in cultural, societal, and personal experiences.

of peace” and “happiness”, and 18 instrumental values (i.e., preferable modes of conduct), such as “courageous”, “honest” and “intellectual”.

A value system reflects the relative importance of all the competing values. In the Rokeach Value Survey (1968; 1973), the relative importance of human values are measured by asking respondents to rank each list in order of importance by writing in numbers from 1 to 18. The relative importance of these values leads to diverse behaviours, particular positions on social issues, and different decisions.

Others have developed alternative measurements of human values, such as the List of Values developed by Kahle (1983; Kahle and Kennedy 1988) and the basic personal values developed by Schwartz (1992). The List of Values (LOV) (1983; Kahle and Kennedy 1988) consists of 9 values, including (1) sense of belonging, (2) excitement, (3) fun and enjoyment in life, (4) warm relationships with others, (5) self-fulfillment, (6) being well-respected, (7) a sense of accomplishment, (8) security, and (9) self-respect. The ten culturally universal basic personal values identified by Schwartz (1992; 2012) are: (1) self-direction, (2) stimulation, (3) hedonism, (4) achievement, (5) power, (6) security, (7) conformity, (8) tradition, (9) benevolence, and (10) universalism.

Although these lists of human values differ in coverage and dimensionality, they have been demonstrated to be valid measures of human values and have significant power in explaining a wide range of human behaviours, such as pro-environmental activities (Dunlap, Grieneeks and Rokeach 1983; Grebitus, Steiner and Veeman 2013; Grebitus, Steiner and Veeman 2015; Grunert and Juhl 1995; Thøgersen and Olander 2002), leisure activities and gift-giving behaviours (Beatty et al. 1985), willingness to pay for fair trade products (DePelsmacker, Janssens and Mielants 2005; DePelsmacker, Driesen and Rayp 2005), and purchasing behaviours of organic foods (Chrysosoidis and Krystallis 2005; Dreezens et al. 2005; Grebitus and Dumortier 2016; Kihlberg and Risvik 2007). A sampling of the empirical studies that examine the relationship between human values and consumer behaviour is presented.

Dunlap, Grieneeks and Rokeach (1983) identified nine values from the Rokeach Value Survey, such as “a world of beauty”, “inner harmony”, “salvation” and “helpful”, which motivate people to engage in pro-environmental behaviours (i.e., being recyclers). DePelsmacker, Janssens and Mielants (2005) and DePelsmacker, Driesen and Rayp (2005) found that personal values as

identified in the Rokeach Value Survey (1973) are extremely relevant in explaining Belgians' attitudes, buying intentions, and willingness-to-pay with respect to fair trade products. Grebitus, Steiner and Veeman (2013) investigated Canadian consumers' food choices for ground beef labelled with carbon and water footprints. Applying the Rokeach Value Survey and a stated preference choice experiment, they found that people who placed more importance on society-centered and interpersonal values are more likely to exhibit environmentally sustainable behaviours than those who consider self-centered and intrapersonal values to be more important. Also, Grebitus, Steiner and Veeman (2015) suggested that human values contribute to a better understanding of German consumers' choices of potatoes labelled with carbon footprints, compared with measures of trust and socio-demographics. They found that people holding strong social orientation terminal values as listed in the Rokeach Value Survey ("freedom", "a world at peace", "equality" and "national security") are more likely to select potatoes labelled with low carbon footprints, relative to people who hold strong personal orientation values ("true friendship" and "self-respect").

Beatty, Kahle, Homer and Misra (1985) identified significant relationships between consumer values and a variety of behaviours. They found that Kahle's (1983; Kahle and Kennedy 1988) List of Values and Rokeach's (1973) human values have significant power in explaining participation in certain leisure activities, preferences for certain television shows and magazines, and gift-giving behaviours. Chryssohoidis and Krystallis (2005) suggested that certain values from the List of Values, such as "self-respect", "enjoyment of life", and "belonging", are the main motivating factors for the purchase of organic products in Greece.

Grunert and Juhl (1995) conducted a study to understand whether Schwartz's value measures can predict Danish teachers' attitudes towards environment-friendly activities and their self-reported buying frequency of organic foods. Results identified values that are important to people holding "green" (pro-environment) attitudes, including "universalism", "benevolence" and "self-direction". Whereas, values of "security", "conformity", "tradition" and "power" are more important to those holding less "green" attitudes. Values of "hedonism", "stimulation" and "achievement" were irrelevant in distinguishing between the two groups of respondents. Similarly, Thøgersen and Olander (2002) found that a selection of basic human values identified in the Schwartz Value Survey, such as "universalism", have a significant influence on Danish consumers'

environment-friendly behaviours. Using the Schwartz Value Survey, Dreezens, Martijn, Tenbult, Kok, et al. (2005) revealed that the value of “power” tended to dispose people towards holding more positive attitudes towards GM food, whereas the value of “universalism” tended to induce more positive attitudes towards organic food.

While the human values discussed above may or may not have direct relevance to food, efforts have also been made to develop specific values that are related to individuals’ food choices. A set of studies explored the motivating factors related to food choice and consumption, such as the Food Choice Questionnaire (FCQ) developed by Steptoe, Pollard and Wardle (1995), the Eating Motivation Survey (TEMS) developed by Renner, Sproesser, Strohbach and Schupp (2012), and the measure of Food Choice Values (FCV) developed by Lyerly and Reeve (2015).

The most prominent effort was made by Lusk and Briggeman (2009) who identified a reasonably comprehensive set of food-specific values that motivate choices between a variety of food products or attributes. Unlike the aforementioned value studies that focused on more *abstract* human values, Lusk and Briggeman (2009) focused on the *intermediary* values that specifically relate to food choices. However, these food values are abstract and stable enough to reflect the “end states” (i.e., outcomes) of food purchase or consumption. They determined a food value system consisting of 11 food values, including (1) naturalness, (2) taste, (3) price, (4) safety, (5) convenience, (6) nutrition, (7) tradition, (8) origin, (9) fairness, (10) appearance, and (11) environmental impact. Using the best-worst scaling method, their study also indicates that, on average, safety, nutrition, taste, and price are the most important values to U.S. consumers, whereas fairness, tradition, and origin are the least important. Also, the relative importance of each food value varies across individuals, and an individual’s food value system has significant power in explaining the preference for organic food. Analysis reveals that the relative importance of values of price, naturalness, and environmental impact drive the preference for organic food within the sample of U.S. consumers surveyed.

Others have made efforts to test and validate the food value scale developed by Lusk and Briggeman (2009), and many show that food values have considerable power in explaining individuals’ food choices. For example, by conducting an online survey of 1950 U.S. consumers, Lister, Tonsor, Brix, Schroeder, et al. (2017) tested the applicability of general food values to specific food products. They applied a slightly modified version of the scale to specific animal

food products: ground beef, beef steak, chicken breasts, and milk. Results indicate that the most (“safety” and “freshness”) and least important food values (“environmental impact”, “animal welfare”, “origin/traceability” and “convenience”) identified by Lusk and Briggeman (2009) still hold when applied to specific livestock food products. A cross-cultural study was conducted by Bazzani, Gustavsen, Nayga and Rickertsen (2016), who compared the relative importance of each food value item to a sample of U.S. and Norwegian consumers by applying the best-worst scaling approach. Results showed that both countries share many similarities. “Safety” and “taste” are ranked as the most important values, whereas “novelty” and “convenience” as the least important value in both countries. However, the value of “price” is significantly more important to the U.S. respondents than to Norwegian respondents. Tirelli, Martinez-Ruiz and Gomez-Ladron-De-Guevara (2013) conducted a study on how food values may influence dietary acculturation of international university students who lived in Spain. Results revealed that, European students consider values related to sustainable production practices such as “fairness”, “origin” and “environmental impact” as more important to their food choices, whereas American students emphasize values related to flavour, appearance and accessibility, such as “taste”, “price”, “convenience”, and “appearance”.

Based on analysis of household scanner data that represent actual grocery store purchases, Lusk (2011) revealed that the values of “environmental impact”, “tradition” and “naturalness”, help to explain a significant amount of variability in consumers’ purchasing behaviours for organic milk and eggs. The greater the levels of importance people place on these values, the more likely they are to buy organic eggs and milk. While consumers who consider “price”, “convenience” and “appearance” as more important food values are less likely to buy organics.

### **4.3 Study Hypotheses**

In light of the preceding literature, this study aims to understand whether consumers’ attitudes towards a novel food technology are an expression of their relatively more stable underlying and fundamental values. Particularly, this study aims to determine whether food values (i.e., the meta-measure of food preferences) are related to people’s preferences for novel food characteristics and nanotechnology.

The first objective of the study is to investigate the applicability of the food values measure developed by Lusk and Briggeman (2009). Food values were developed to reflect more stable food-specific human values that may change due to cultural or societal context. Because of the geographic proximity between Canada and the U.S., I consider the following hypothesis:

**H<sub>1</sub>:** food values identified in previous studies as important (unimportant) to U.S. consumers are also important (unimportant) to Canadian consumers.

This study also aims to examine the power of the food values scale in explaining preferences for novel food attributes and technologies, as such I hypothesize:

**H<sub>2</sub>:** underlying food values help explain preferences for novel food attributes (non-browning, antioxidant-enhanced) and food processing technologies (novel nano-coating, conventional edible-coating) included in the study.

In order to test these proposed hypotheses, consumer data were collected from an online national survey. The next section describes the design of the nanotechnology survey.

#### **4.4 Survey and Data**

Consumer data for this study were collected from the ‘Nano’ survey as described in Section 2.4 in chapter 2. Two versions of the online survey were initially developed, one focused on ‘Biotechnology’, and the other on ‘Nanotechnology’. The ‘Bio’ survey data have been extensively analyzed in the preceding two chapters, which explored the effects of information framing and cultural values on acceptance of food biotechnology, respectively. In this chapter, the ‘Nano’ survey data are analyzed to examine the influences of food values on preferences for food nanotechnology.

After removing the suspect responses, the final ‘Nano’ dataset consists of 710 respondents and 4260 choice observations. In the interests of brevity, this section will not repeat the description of the survey design (section 2.4.1), the sample characteristics (section 2.4.2), and the design of the choice experiment (section 2.5), as the ‘Nano’ survey mirrors the ‘Bio’ survey in terms of design, layout, question wording and length (see Appendix B for the complete ‘Nano’ survey instrument). I describe here only the sections that are relevant for this study and that differ with the ‘Bio’ survey.

The ‘Nano’ survey starts with a set of questions related to food values (Lusk and Briggeman 2009). Respondents were asked how important each of the 11 food values are to their food purchase on a 6-point scale (1=not at all important, 6=extremely important, see Appendix B question [FV]).<sup>31</sup> The 11 food value items were developed by Lusk and Briggeman (2009). and have been widely used in other studies (Lusk 2011; Lister et al. 2017; Tirelli, Martinez-Ruiz and Gomez-Ladron-De-Guevara 2013). The scale of food values includes naturalness, taste, price, safety, convenience, nutrition, novelty, origin, fairness, appearance and environmental impact.

The importance rating questions were also followed by a ranking task, in which respondents were asked to make trade-offs by selecting the 3 most important and 3 least important value items that motivate their food purchases (see Appendix B question [FV\_RANK]). Responses to these food value questions are analyzed in section 4.6.1 for a general understanding of Canadian consumers’ food value systems and in section 4.6.2 for a more nuanced understanding of what effects food values may have on food choice behaviours.

In the online survey respondents reported as being very unfamiliar with nanotechnology, with a vast majority (83.24%) of respondents indicated that they either knew ‘nothing at all’ or ‘just a little’ about food nanotechnology, and the remaining 16.76% knew ‘some’ or ‘a lot’ (Appendix B question [KNOW]). As such, a generic and neutral introductory information about food nanotechnology was provided to all respondents regardless of the information conditions.<sup>32</sup> In this

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<sup>31</sup> There were two additional values included in the survey: social image and familiarity. These two values were included as they were shown to be important motivating factors for food choices (Steptoe, Pollard and Wardle 1995; Renner et al. 2012). However, they were excluded from the final data analyses, due to their insignificance in explaining choice behaviours of sliced apple products and inconsistency with the food values items.

<sup>32</sup> Similar with the ‘Bio’ survey, in addition to the generic introductory information, respondents were also provided with additional detailed information on food nanotechnology before they entered the choice experiment. The additional information introduces nano-coating as a food processing method and explains how it works differently with the conventional edible-coating method to obtain the non-browning and antioxidant-enhanced apple characteristics (see Appendix B section [Information Conditions]). Respondents were randomly allocated to one of the four information conditions, including ‘No Additional Information (Control)’ condition, ‘Logical-scientific’, ‘Narrative’, and ‘Self-selection’ condition.

The ‘Nano’ dataset was analyzed with similar models used in Chapter 2, which focuses on exploring the information framing effects. However, no significant informational effects were identified in the ‘Nano’ dataset. That is, different frames of nanotechnology fail to generate any

general piece of information, nanotechnology was described as the techniques allowing scientists to measure, see, and make things on a very, very small scale, and hence scientists are using nanotechnology to develop apple products with additional benefits, such as ready-to-eat non-browning apple slices, and sliced apples with enhanced levels of antioxidants like Vitamin C (for exact wording of information, see Appendix B, question [GENERIC] and [GENERAL]).

Respondents' food choice behaviours were then captured by a choice experiment, in which they were asked to make 6 consecutive food choices. As discussed in section 2.5, a choice experiment is a quantitative tool to elicit preferences for different (food) attributes by asking people to select the most preferred (food) choice from a set of hypothetical alternatives that are experimentally designed. Observing respondents' choice behaviours allows investigating how people assess different novel food attributes and technologies.

Respondents were asked to choose between a set of 500g bags of pre-packaged apple slices that vary in four features: (1) *appearance* of apple slices, apples can turn brown in minutes after being sliced or resist browning for a long time; (2) *health benefit*, sliced apples are enhanced with higher levels of dietary antioxidants like Vitamin C or contain only a regular amount of antioxidants; (3) *processing method*, the aforementioned two novel apple characteristics can be introduced through either a novel nano-coating or a conventional edible-coating method.<sup>33</sup> Apples not subject to any

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differing attitudinal responses or choice behaviours in this study. As such, data were pooled across information conditions for the analyses in this chapter.

One possible reason for the insignificant information framing effects is that consumers are less familiar with nanotechnology relative to biotechnology. In the 'Nano' survey, a vast majority (83.24%) of respondents indicated that they either knew 'nothing at all' or 'just a little' about food nanotechnology, and the remaining 16.76% knew 'some' or 'a lot' (Appendix B question [KNOW]). By contrast, in the 'Bio' survey, a lower percentage (63.42%) of respondents indicated they knew 'nothing at all' or 'just a little' about biotechnology, while more respondents (36.58%) indicated they knew 'some' or 'a lot' (Appendix A question [KNOW]).

As such, when individuals get exposed to 'new' information about nanotechnology, their attitudes and behaviours appear less likely to be affected by the information formats. By contrast, for individuals who consider themselves to be more knowledgeable or familiar with the technology, such as those in the 'Bio' study, how the 'new' information is presented to them appears to matter and may have greater impacts in shaping attitudes and behaviours. However, further studies are needed to confirm this assumption.

<sup>33</sup> The *conventional edible-coating* method was described in the choice experiment as a food processing method that involved "dipping sliced apples in a solution such as calcium ascorbate



additional processing to prevent browning or enhance antioxidants will possess none of the novel characteristics; and (4) the retail *price* for a 500g bag of apple slices. Table 4.1 summarizes the attributes and levels included in the study.

**Table 4.1 Attributes and Levels in Choice Experiment**

Attribute	Levels		
Appearance	Non-browning	Slices turn brown	
Health Benefit	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants	
Processing Method	Nano coating	Conventional coating	No additional Processing
Price	\$3.69	\$4.29	\$4.89

The technical detail of the choice experiment, including the selection of attributes and levels, the efficient experiment design, and the blocked choice design have already been discussed in detail in section 2.5. In total, a *D-efficient* design generates 36 choice sets, each of which consists of 3 hypothetical product alternatives and 1 opt-out option (see Table 4.2 for an example).

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prior to packaging”. The *novel nano-coating* was described as “a more effective edible coating method using nanotechnology, which deals with things at very very small scale”. The *no additional processing* was described as “sliced apples are produced without using additional food processing methods”. See Appendix B section [Choice Experiment] for the exact wording.

**Table 4.2 Example of a Choice Set**

Imagine that you are actually buying a 500g bag of apple slices in a real grocery store. If you were able to select from the following options, which one would you buy?

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>Appearance</b>	Slices turn brown	Non-browning	Slices turn brown	
<b>Health Benefit</b>	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants	Not enhanced with antioxidants	I would not buy any of these products
<b>Processing Method</b>	Nano coating	Conventional coating		
<b>Price</b>	\$4.29	\$3.69	\$4.89	
<b>I would choose...</b>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

To reduce the number of choice tasks that respondents need to complete in the survey, the 36 choice sets were blocked into 6 sets with 6 questions in each block. Each participant was randomly assigned into a block, and answered 6 choice questions. As such, a total of 4260 choice observations were obtained from 710 respondents. These choice data are analyzed by four choice models specified in the following section 4.5, and the estimation results are presented in section 4.6.2.

Attitudinal questions about food nanotechnology, such as the level of familiarity, objective knowledge, risk/benefit perceptions, trust in information sources, etc., and demographic characteristics, were also asked to respondents before they exited the online survey.

#### 4.5 Model Specification

Choices made by respondents in the discrete choice experiment are analyzed using a set of choice models. I start with estimating a basic multinomial logit (MNL) model which serves a benchmark model. To account for any preference heterogeneity and the panel nature of choice data, I also estimate a random parameter logit (RPL) model and two varieties of latent class model (LCM). Unlike the RPL model that requires *a priori* assumptions on the preference distribution and the

sources of preference heterogeneity, LCMs will identify different consumer segments (heterogeneity) based on a statistical procedure. This section specifies each choice model and discusses their respective strengths and limitations.

#### 4.5.1 Multinomial Logit Model (MNL)

To analyze the consumer choice data, a basic multinomial logit model (MNL) and a latent class model (LCM) are estimated. As described in section 3.5.1 in chapter 3, the choice modeling approaches are based on the random utility model developed by McFadden (1974). The utility ( $U_{nsj}$ ) individual  $n$  derives from alternative  $j$  in choice set  $s$  is defined as:

$$U_{nsj} = V_{nsj} + \varepsilon_{nsj} = x'_{nsj}\beta + \varepsilon_{nsj} \quad j = 1, 2, \dots, J \quad s = 1, 2, \dots, S \quad n = 1, 2, \dots, N \quad (4.1)$$

Where  $V_{nsj}$  denotes a deterministic and observed component of the utility function consisting of a vector of attribute variables ( $x'$ ) and the associated model parameters ( $\beta$ ) to be estimated. The inclusion of a random and unobserved component,  $\varepsilon_{nsj}$ , is consistent with the fact that researchers are unable to capture all factors that may influence choice behaviours and/or detect all the processing heuristics respondents employed when making their choices (Louviere, Hensher and Swait 2000). In a standard MNL model, the random component ( $\varepsilon_{nsj}$ ) is assumed to be identically and independently distributed (i.i.d.) as a type 1 extreme value (EV1).

In this study, various product attributes enter the model as dummy-coded variables. The underlying utility function is hence specified as follows:

$$U_{nsj} = \beta_{NB}NB_{nsj} + \beta_{AE}AE_{nsj} + \beta_{NC}NC_{nsj} + \beta_{EC}EC_{nsj} + \beta_{PRI}PRI_{nsj} + \varepsilon_{nsj} \quad (4.2)$$

Where  $NB_{nsj}$ ,  $AE_{nsj}$ ,  $NC_{nsj}$ ,  $EC_{nsj}$ , and  $PRI_{nsj}$  denote the levels of the attribute variables non-browning, antioxidant-enhanced, nano-coating, edible-coating, and price, respectively.

As a utility maximizer, an individual  $n$  will choose alternative  $i$  if and only if the  $i$ th alternative yields the highest utility among the  $J$  alternatives in choice set  $s$ .

$$P_{nsi} = Prob(V_{nsi} + \varepsilon_{nsi} \geq V_{nsj} + \varepsilon_{nsj}) \quad \forall j \neq i \quad (4.3)$$

Thus, the probability of individual  $n$  choosing alternative  $i$  with attributes  $x'$  in choice set  $s$  can be expressed as (Train 2009):

$$P_{nsi} = \frac{\exp(V_{nsi})}{\sum_j \exp(V_{nsj})} = \frac{\exp(x'_{nsi}\beta)}{\sum_j \exp(x'_{nsj}\beta)} \quad (4.4)$$

As discussed in section 3.5.1, a MNL is limited in that it is unable to capture heterogeneous preferences but rather assumes homogeneous preferences among individuals (Train 2009).<sup>34</sup> To account for preference heterogeneity and to accommodate the panel nature of the choice data (i.e., in the choice experiment, each respondent was asked to make six repeated choices), the latent class model (LCM) is also estimated.

#### 4.5.2 Latent Class Model (LCM)

Traditionally, preference heterogeneity is captured by making *a priori* assumptions on observable individual characteristics that can cause heterogeneous preferences. For example, when a gender (or other individual characteristics such as age, income, etc.) difference is assumed to influence preferences for certain attributes, the ‘gender’ variable could enter the choice modelling through two ways. One way is to interact the ‘gender’ variable with various attribute variables, as such any gender heterogeneity in preferences (tastes) can be accounted for. Another way is to group respondents into segments based on ‘gender’ and then estimate choice models separately for each segment. Both methods are limited in that they require *a priori* assumptions (ideally based on theoretical insights) and the selection of individual characteristics that influence preferences and thus should be incorporated into the choice models (Boxall and Adamowicz 2002).

The development of a random parameter logit (RPL) model allows the researcher to account for random preference heterogeneity by assuming that preference parameters vary randomly among individuals. However, the RPL model requires researchers to make assumptions on distributions of these random parameters. For example, preference parameters are assumed to be randomly and normally (or log-normally) distributed over individuals. To further explain the sources of heterogeneity, the RPL also allows preference (taste) parameters to vary systematically with

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<sup>34</sup> In a MNL model, the error component ( $\varepsilon_{nsj}$ ) is assumed to be independent across alternatives ( $j$ ), choice situations ( $s$ ), and individuals ( $n$ ). As such, only taste heterogeneity that is associated with observable individual characteristics, such as age, income, etc., can be accounted for by a MNL model via interaction terms. When assuming a random preference heterogeneity that is not associated with observable factors, models that allow for more flexible error correlations are needed (Train 2009).

individual characteristics ( $Z_n$ ) by specifying  $\beta_n = \beta + \Delta Z_n + \Gamma v_n$ , where  $v_n$  is the random variate distributed normally or log-normally among individuals ( $n$ ). However, this procedure is essentially equivalent to the method of interacting individual characteristics with attribute variables, but it additionally includes a random component into the choice model. As such, the RPL model is limited in accounting for and explaining preference heterogeneity as it requires an *a priori* assumption on the distribution of the random preference component ( $v_n$ ) and *a priori* knowledge and selection of individual characteristics ( $Z_n$ ) that relate to preference heterogeneity and thus should enter the model.

To account for preference heterogeneity, both the traditional methods (interacting individual characteristics with attribute variables or estimating separate choice models for each consumer segment based on their individual characteristics) and the more advanced RPL model require *a priori* knowledge on the individual characteristics that may relate to preference heterogeneity and/or assumptions on distribution of random preference parameters.

To account for these limitations, this study utilizes the latent class model (LCM). Without making any *a priori* assumptions and selection of consumer characteristics, LCM allows the identification of different consumer segments characterized by distinct preference patterns based on the choice behaviours captured in a choice experiment.

The LCM assumes that there exists  $Q$  segments or classes of consumers in a population and that individual  $n$  belongs to the segment  $q$  ( $q=1, 2 \dots Q$ ). Unlike the generic preference parameters specified in equation (4.4),  $\beta$ , the utility parameters now become segment-specific ( $\beta_q$ ) and the choice probability function *conditional* on individual  $n$  belongs to segment  $q$  is given as:

$$P_{nsi|q} = \frac{\exp(x'_{nsi}\beta_q)}{\sum_j \exp(x'_{nsj}\beta_q)} \quad (4.5)$$

Where  $P_{nsi|q}$  is the probability of individual  $n$ , who belongs to segment/class  $q$ , choosing alternative  $i$  in choice set  $s$ ;  $x'_{nsi}$  is a vector of attribute variables; and  $\beta_q$  is a vector of associated preference parameters that are segment-specific.

The class membership probability ( $P_{nq}$ ) that individual  $n$  belongs to segment  $q$  is parameterized in a multinomial logit formulation to impose the restrictions of  $\sum_q P_{nq} = 1$  and  $0 \leq P_{nq} \leq 1$ :

$$P_{nq} = \frac{\exp(\theta_q)}{\sum_q \exp(\theta_q)} \quad q = 1, 2, \dots, Q \quad \theta_Q = 0 \quad (4.6)$$

Where  $\theta_q$  is a vector of segment-specific parameters to estimate. The  $Q$ th parameter is normalized to zero for the purpose of model identification, i.e.,  $\theta_Q = 0$ . Until now, the model does not involve any pre-selection of individual characteristics to help segment consumers with heterogeneous preferences. Instead, the LCM will simultaneously estimate the class memberships and the choices.

To better understand the sources of preference heterogeneity among consumers, a refinement of the LCM would allow for characterizing segments or classes from observed or latent individual characteristics. Following Boxall and Adamowicz (2002), let  $M_{nq}^*$  denote an unobservable (i.e., latent) membership likelihood function that is determined by a set of individuals' latent attitudinal measures (e.g., unobservable underlying food values in this study) and/or observed socioeconomic characteristics (e.g., age, income). For an individual  $n$ , the (latent) likelihood that he/she belongs to segment  $q$  can be described as:

$$M_{nq}^* = \gamma_{pq} P_n^* + \gamma_{sq} S_n + \mu_{nq} \quad (4.7)$$

$$P_n^* = \delta_p P_n + \mu_n \quad (4.8)$$

Where  $M_{nq}^*$  is the latent membership likelihood function for individual  $n$  classified into segment  $q$ ;  $P_n^*$  represents a set of individual  $n$ 's latent attitudinal or psychometric measures and  $\gamma_{pq}$  are associated parameters;  $S_n$  is a set of observed socioeconomic characteristics of individual  $n$  and  $\gamma_{sq}$  are associated parameters;  $P_n$  is a vector of observed indicators of the latent psychometric measures and  $\delta_p$  are associated parameters;  $\mu_{nq}$  and  $\mu_n$  are error terms in respective latent functions. Replacing  $P_n^*$  in equation (4.7) by equation (4.8) yields:

$$M_{nq}^* = \gamma_{pq} \delta_p P_n + \gamma_{sq} S_n + (\gamma_{pq} \mu_n + \mu_{nq}) \quad (4.9)$$

Denote  $Z_n$  as a set of observable individual characteristics including both observed psychometric indicators ( $P_n$ ) and socioeconomic characteristics ( $S_n$ );  $\theta_q$  as a vector of associated parameters to be estimated; and  $\epsilon_{nq}$  as the composite error term, equation (4.9) can be re-written as:

$$M_{nq}^* = Z_n' \theta_q + \epsilon_{nq} \quad q = 1, 2, \dots, Q \quad n = 1, 2, \dots, N \quad (4.10)$$

We, as researchers, will ‘observe’ individual  $n$  belongs to segment  $q$  if and only if when the latent likelihood  $M_{nq}^*$  is greater or equal to the latent likelihood that individual  $n$  belongs to any other segments  $t$ ,  $M_{nt}^*$ ,  $\forall t \neq q$   $t = 1, 2, \dots, Q$ . That is, the probability of individual  $n$  belonging to segment  $q$  is expressed as:

$$P_{nq} = \text{Prob}(M_{nq}^* \geq M_{nt}^*) = \text{Prob}(Z_n' \theta_q + \epsilon_{nq} \geq Z_n' \theta_t + \epsilon_{nt}) \quad \forall t \neq q \quad t = 1, 2, \dots, Q \quad (4.11)$$

To impose the restrictions on class probabilities that  $\sum_q P_{nq} = 1$  and  $0 \leq P_{nq} \leq 1$ , we employ a particularly convenient assumption that the error terms are identically and independently distributed (i.i.d., across individuals  $n$  and segments  $q$ ) Type 1 extreme value variates (Boxall and Adamowicz 2002; Hensher, Rose and Greene 2015). As a result, the probability of individual  $n$  in segment  $q$  will take a multinomial logit form:

$$P_{nq} = \frac{\exp(Z_n' \theta_q)}{\sum_q \exp(Z_n' \theta_q)} \quad q = 1, 2, \dots, Q \quad \theta_Q = 0 \quad (4.12)$$

Where  $\theta_q$  is a set of segment-specific parameter vectors to estimate, and the  $Q$ th parameter vector is normalized to zero for identification purpose. The class membership probabilities are now dependent on individual characteristics.

The membership probability function has a similar multinomial logit formulation as the choice probability as shown in equation (4.5). However, unlike the choice probability, which is a function of choice attributes, the class membership probability is determined by class membership variables ( $Z_n$ ) including individuals’ attitudinal measures and/or their socioeconomic characteristics.

Given the *conditional* choice probability ( $P_{nsi|q}$ ) and the class membership probability ( $P_{nq}$ ), the *unconditional* probability that individual  $n$  choose alternative  $i$  in choice set  $s$  is expressed as:

$$P_{nsi} = \sum_q P_{nq} P_{nsi|q} \quad (4.13)$$

That is, taking the expectation of the class-specific probabilities over classes. Substituting class membership probability function (4.12) and *conditional* choice probability function (4.5), the *unconditional* probability function takes the joint distribution form:

$$P_{nsi} = \sum_q \frac{\exp(Z'_n \theta_q)}{\sum_q \exp(Z'_n \theta_q)} \frac{\exp(x'_{nsi} \beta_q)}{\sum_j \exp(x'_{nsj} \beta_q)} \quad (4.14)$$

That is, the unconditional probability is obtained by multiplying the conditional choice probability (conditional on being in a specific segment  $q$ ) with the probability of being in a segment  $q$  and then integrating over all possible segments  $Q$ . The joint distribution of class membership probability and choice probability indicates that choice behaviour is explained by both the choice attribute variables ( $x'_{nsi}$ ) and individual-specific characteristics ( $Z'_n$ ) in a LCM model.

When  $\theta_q = 0$  and  $\beta_q = \beta$  for all  $q = 1, 2, \dots, Q$ , the LCM model (equation (4.14)) reduces to the standard MNL model (equation (4.4)). These conditions are essentially restricting the preference homogeneity among individuals who all belong to the same single segment. That is, the MNL represents the single segment case by assuming perfect preference homogeneity. The RPL model represents the situation in which each individual is a segment (i.e.,  $Q=N$ ) and hence has his/her own preference parameters. Thus, a LCM model lies between the MNL and RPL models by allowing for some degree of preference heterogeneity and providing better information on consumer segments.<sup>35</sup>

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<sup>35</sup> In the RPL model, the *unconditional* probability is obtained by integrating the *conditional* probability over all possible values of taste parameters, which are assumed to follow normal, log-normal, or other distributions:

$$P_{nsi} = \int \frac{\exp(x'_{nsi} \beta_n)}{\sum_j \exp(x'_{nsj} \beta_n)} f(\beta_n | \Omega) d\beta_n \quad (4.15)$$

By contrast, the LCM model is a finite mixture model as the underlying membership probability is discrete in nature (see equation (4.12)). That is, the segment membership probability function ( $P_{nq}$  in equation (4.13)) is the finite analogue to the continuous distributions assumed in a RPL model ( $f(\beta_n | \Omega)$  in equation (4.15)) (Boxall and Adamowicz 2002).

The LCM is therefore less flexible than the RPL model as it approximates the underlying continuous distribution with a discrete one; however, it does not require the establishment of *a priori* assumptions about the distributions of parameters across individuals. Thus, each model has its limitations and virtues (Hensher, Rose and Greene 2015).



In the choice experiment, each respondent answered a sequence of six repeated choices. For a given class assignment  $q$ , the likelihood of individual  $n$  making a sequence of choices is the joint probability of making a sequence of  $S$  choices, given as:<sup>36</sup>

$$P_{n|q} = \prod_s \prod_i P_{nsi|q}^{y_{nsi}} \quad (4.16)$$

The likelihood for individual  $n$  is the expectation of the class-specific likelihoods, given as:

$$P_n = \sum_q P_{nq} P_{n|q} = \sum_q P_{nq} \left( \prod_s \prod_i P_{nsi|q}^{y_{nsi}} \right) \quad (4.17)$$

Hence, the log-likelihood function for the sample is characterized as:

$$\begin{aligned} LL &= \sum_n \ln P_n = \sum_n \ln \left[ \sum_q P_{nq} \left( \prod_s \prod_i P_{nsi|q}^{y_{nsi}} \right) \right] \\ &= \sum_n \ln \left[ \sum_q \left( \frac{\exp(Z'_n \theta_q)}{\sum_q \exp(Z'_n \theta_q)} \right) \left( \prod_s \prod_i \left( \frac{\exp(x'_{nsi} \beta_q)}{\sum_j \exp(x'_{nsj} \beta_q)} \right)^{y_{nsi}} \right) \right] \end{aligned} \quad (4.18)$$

Where  $y_{nsi}$  is an indicator function taking a value of 1 if individual  $n$  chooses alternative  $i$  in choice set  $s$ , and 0 otherwise. Model parameters,  $\theta_q$  and  $\beta_q$ , are estimated using the maximum likelihood method. For identification purposes, membership parameters for  $Q$ th segment must be normalized to 0, i.e.,  $\theta_Q = 0$ . The maximum likelihood estimation will solve for  $Q$  structural choice parameter vectors,  $\hat{\beta}_q$ , and the  $Q-1$  latent class parameter vectors,  $\hat{\theta}_q$ , that maximizes the log-likelihood function.

In sum, the LCM provides an alternative approach to the MNL and RPL models to accommodate preference heterogeneity. It assumes that the population consists of  $Q$  latent (i.e., unknown by researchers) segments or classes of individuals. The groups are heterogeneous in preferences,

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<sup>36</sup> It is noteworthy that an implicit assumption in equation (4.16) is that, given the class assignment  $q$ , the choices made by individual  $n$  in  $S$  choices situations are independent. This is a strong assumption especially given the ‘panel’ nature of choice data (Hensher, Rose and Greene 2015). This strict assumption will be relaxed in a more advanced latent class model specified later, the random parameter latent class (RP-LCM) model.

however, members in the same group have homogeneous preferences, as the model parameters,  $\theta_q$  and  $\beta_q$ , are segment-specific only.

Also, the LCM does not require *a priori* knowledge on possible sources of heterogeneity. The segments are determined by individuals' choice patterns observed in a choice experiment, and the choice models estimate the class memberships and choice behaviours simultaneously in the statistical procedures. A refined LCM also allows the segments to be determined by individual characteristics, which can include observed indicators of latent attitudinal or psychometric measures and observed socioeconomic factors. As such, the specific choice patterns of individuals and their characteristics will both influence which (latent) segment they belong to, and more importantly, such class assignments are not completely determined by *a priori* assumptions, but are rather derived from statistical procedures.

Further, by identifying heterogeneous segments of consumers and characterizing their choice behaviours, the LCM offers an opportunity to identify 'who' comprises the population of interest and who would be affected by certain policy changes. Finally, the LCM posits that the segment-specific preference parameters are distributed among individuals with a discrete distribution rather than the continuous distribution in a RPL model. As such, the LCM indicates that, within in each class, choice behaviours are characterized by a MNL specification. That is, within each class, preferences are perfectly homogeneous, the independence from irrelevant alternatives (IIA) assumption still holds, and choices are made independently across individuals and choice sets. To relax these limitations, a more advanced version of LCM is specified in this study.

#### **4.5.3 Random Parameter Latent Class Model (RP-LCM)**

In the standard LCM, preferences are heterogeneous only across classes, but are perfectly homogeneous within each class. A more advanced version of the LCM, the random parameter latent class model (RP-LCM) adds an additional layer of preference heterogeneity by permitting random parameters within each latent segment (Hensher, Rose and Greene 2015).

In a RP-LCM, the preference parameters within a specific segment ( $\beta_q$ ) are no longer assumed as fixed or homogeneous among individuals, rather are structured (similarly as in a RPL model) as a continuous distribution (Hensher, Rose and Greene 2015):

$$\beta_{n|q} = \beta_q + \omega_{n|q}, \quad E(\omega_{n|q}) = 0 \quad Var(\omega_{n|q}) = \Sigma_q \quad (4.19)$$

where  $\omega_{n|q}$  is a vector of random variates assumed to be normally distributed across individuals (in segment  $q$ ) with mean 0 and covariance matrix  $\Sigma_q$  (i.e.,  $\omega_{n|q} \sim N(0, \Sigma_q)$ ), hence  $\omega_{n|q}$  captures any within-class heterogeneity.

By allowing for a panel data setting (relaxing the assumption of independence of choices made by a respondent as in the standard LCM model), the likelihood for individual  $n$  given a class assignment  $s$  is:

$$P_{n|q} = \int \prod_s \prod_i (P_{nsi|q}(\beta_q + \omega_{n|q}))^{y_{nsi}} f(\omega_{n|q}) d\omega_{n|q} \quad (4.20)$$

The likelihood for individual  $n$  is given as:

$$P_n = \sum_q P_{nq} P_{n|q} = \sum_q P_{nq} \left( \int \prod_s \prod_i (P_{nsi|q}(\beta_q + \omega_{n|q}))^{y_{nsi}} f(\omega_{n|q}) d\omega_{n|q} \right) \quad (4.21)$$

The class probabilities ( $P_{nq}$ ) are the same as specified in equation (4.12). Hence, the log-likelihood function for the sample is shown as:

$$\begin{aligned} LL = \sum_n \ln P_n &= \sum_n \ln \left[ \sum_q P_{nq} \left( \int \prod_s \prod_i P_{nsi|q}(\beta_q + \omega_{n|q})^{y_{nsi}} f(\omega_{n|q}) d\omega_{n|q} \right) \right] = \\ &\sum_n \ln \left\{ \sum_q \frac{\exp(Z'_n \theta_q)}{\sum_q \exp(Z'_n \theta_q)} \left[ \int \prod_s \prod_i \left( \frac{\exp(x'_{nsi}(\beta_q + \omega_{n|q}))}{\sum_j \exp(x'_{nsj}(\beta_q + \omega_{n|q}))} \right)^{y_{nsi}} f(\omega_{n|q}) d\omega_{n|q} \right] \right\} \end{aligned} \quad (4.22)$$

Just like RPL, the integrals in equation (4.22) have to be evaluated using a maximum simulated likelihood method. Collecting all terms, the simulated log-likelihood function is shown as:

$$SLL = \sum_n \ln \left\{ \sum_q \frac{\exp(Z'_n \theta_q)}{\sum_q \exp(Z'_n \theta_q)} \left[ \frac{1}{R} \sum_r \left( \prod_s \prod_i \frac{\exp(x'_{nsi}(\beta_q + \omega_{n|q}^r))}{\sum_j \exp(x'_{nsj}(\beta_q + \omega_{n|q}^r))} \right)^{y_{nsi}} \right] \right\} \quad (4.23)$$

Where  $\omega_{n|q}^r$  is the  $r$ th of  $R$  random draws from the assumed distributions (i.e., normal) of the random vector  $\omega_{n|q}$ ;  $\theta_Q = 0$  for model identification purposes; and  $y_{nsi}$  is an indicator function taking a value of 1 if individual  $n$  chose alternative  $i$  in choice set  $s$ , and 0 otherwise. The maximum

simulated likelihood estimation will solve for  $Q$  structural choice parameter vectors,  $\hat{\beta}_q$ , and the  $Q-1$  latent class parameter vectors,  $\hat{\theta}_q$ , that maximizes the simulated log-likelihood function.

In sum, the RP-LCM is the most advanced LCM as it combines a standard LCM and a RPL model by allowing for heterogeneity both within and across classes. The RP-LCM extends the standard LCM by permitting continuous distributions in each discrete class for the class-specific parameters.

This chapter examines whether individuals' food values help explain their preferences for different novel food attributes and nanotechnology. As such, respondents' food value scores are incorporated in different choice models. As shown in equations (4.24) – (4.27), food values enter the choice models either via interaction terms in the MNL and RPL models, or through individual psychometric variables that determine the class probabilities in the two LCM models.

$$\begin{aligned}
 \textbf{MNL: } U_{nsj} = & (\beta_{NB} + \gamma_1 \text{Food Values}_n) \times NB_{nsj} + (\beta_{AE} + \gamma_2 \text{Food Values}_n) \times AE_{nsj} \\
 & + (\beta_{NC} + \gamma_3 \text{Food Values}_n) \times NC_{nsj} + (\beta_{EC} + \gamma_4 \text{Food Values}_n) \times EC_{nsj} \\
 & + (\beta_{PRI} + \gamma_5 \text{Food Values}_n) \times PRI_{nsj} + \varepsilon_{nsj}
 \end{aligned} \tag{4.24}$$

$$\begin{aligned}
 \textbf{RPL: } U_{nsj} = & \beta_{NB,n} NB_{nsj} + \beta_{AE,n} AE_{nsj} + \beta_{NC,n} NC_{nsj} + \beta_{EC,n} EC_{nsj} + \beta_{PRI,n} PRI_{nsj} + \varepsilon_{nsj} \\
 \beta_n = & \beta + \Delta \times \text{Food Values}_n + \Gamma v_n
 \end{aligned} \tag{4.25}$$

$$\begin{aligned}
 \textbf{LCM: } P_n = & \sum_q P_{nq} P_{n|q} = \sum_q P_{nq} \left( \prod_s \prod_i P_{nsi|q}^{y_{nsi}} \right) \\
 P_{nq} = & \frac{\exp(\text{Food Values}'_n \theta_q)}{\sum_q \exp(\text{Food Values}'_n \theta_q)} \\
 P_{nsi|q} = & \frac{\exp(\beta_{NB} NB_{nsj} + \beta_{AE} AE_{nsj} + \beta_{NC} NC_{nsj} + \beta_{EC} EC_{nsj} + \beta_{PRI} PRI_{nsj})}{\sum_j \exp(\beta_{NB} NB_{nsj} + \beta_{AE} AE_{nsj} + \beta_{NC} NC_{nsj} + \beta_{EC} EC_{nsj} + \beta_{PRI} PRI_{nsj})}
 \end{aligned} \tag{4.26}$$

**RP – LCM:**

$$P_n = \sum_q P_{nq} P_{n|q} = \sum_q P_{nq} \left( \int \prod_s \prod_i (P_{nsi|q}(\beta_q + \omega_{n|q}))^{y_{nsi}} f(\omega_{n|q}) d\omega_{n|q} \right)$$

$$P_{nq} = \frac{\exp(\text{Food Values}'_n \theta_q)}{\sum_q \exp(\text{Food Values}'_n \theta_q)}$$

$$P_{nsi|q} = \frac{\exp(\beta_{NB}NB_{nsj} + \beta_{AE}AE_{nsj} + \beta_{NC}NC_{nsj} + \beta_{EC}EC_{nsj} + \beta_{PRI}PRI_{nsj})}{\sum_j \exp(\beta_{NB}NB_{nsj} + \beta_{AE}AE_{nsj} + \beta_{NC}NC_{nsj} + \beta_{EC}EC_{nsj} + \beta_{PRI}PRI_{nsj})} \quad (4.27)$$

All the choice models described in this section are estimated in statistical package Nlogit 6 (Econometric Software Inc.). The MNL and LCM models are estimated by the maximum likelihood method, and the RPL and RP-LCM models are estimated by maximum simulated likelihood with 200 Halton draws. Estimation results are presented in the following section.

#### 4.6 Results and Discussion

Consumers' attitudes towards novel food technologies and their choice behaviours captured in a choice experiment are analyzed in this section. Two sets of analyses are conducted. Section 4.6.1 summarizes the food values system observed among the sampled Canadian population, and compares my findings with other food value studies. Section 4.6.2 discusses how food values influence preferences for novel food attributes and technologies by presenting the estimation results of four choice models specified in section 4.5.

Before presenting the empirical results, Table 4.3 provides a full list of variables included in the analysis and describes how they were coded for model estimations.

**Table 4.3 Coding of Variables**

	<b>Description</b>	<b>Coding</b>
<b><i>Attributes</i></b>		
NB	Non-browning	= 1 if apple slices do not turn brown quickly after being sliced; 0 otherwise
AE	Enhanced with antioxidants like Vitamin C	= 1 if apple slices are enhanced with higher level of dietary antioxidants; 0 otherwise
NC	Nano-coating	= 1 if desirable apple traits are achieved by the nano-coating technique; 0 otherwise
EC	Edible-coating	= 1 if desirable apple traits are achieved by the conventional edible-coating method; 0 otherwise
PRI	The price levels included in choice experiment for a 500g bag of apple slices, ranging from \$3.69 to \$4.89	Continuous
No-purchase	Indicator variable for the opt-out option in choice experiment	= 1 if "I would not buy any of these products" option is selected in a choice set; 0 otherwise
<b><i>Food Value Covariates</i></b>		
Naturalness	Rating score for importance of 'naturalness' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Taste	Rating score for importance of 'taste' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Price	Rating score for importance of 'price' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Safety	Rating score for importance of 'safety' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Convenience	Rating score for importance of 'convenience' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Nutrition	Rating score for importance of 'nutrition' to food purchase 1= Not At All Important 6= Extremely Important	Continuous

Novelty	Rating score for importance of 'novelty' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Origin	Rating score for importance of 'origin' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Fairness	Rating score for importance of 'fairness' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Appearance	Rating score for importance of 'appearance' to food purchase 1= Not At All Important 6= Extremely Important	Continuous
Environmental Impact	Rating score for importance of 'environmental impact' to food purchase 1= Not At All Important 6= Extremely Important	Continuous

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#### 4.6.1 Descriptive Analysis

As this study aims to understand the role of food values in affecting consumer evaluations of food technology, the web-based survey first collected data on individuals' perceptions of the importance of each food value to their food purchase decisions. Two set of questions were asked to respondents: one rating task and one ranking task involving trade-offs. Each respondent was asked to indicate how important a list of 11 food value issues were when buying food, based on a 6-point scale (1 = not at all important, 6 = extremely important, see Appendix B section [Values] – FV). Then, respondents were asked to make trade-offs between these 11 food value items by selecting the 3 most important and the 3 least important items that motivate their food purchases (see Appendix B section [Values] – FV\_RANK for the exact question wording).

This section explores individuals' evaluations of food values in general. The impacts of these food values on food choice behaviours is analyzed in the subsequent section 4.6.2. The importance of 11 food values is ranked based on the average rating scores among the sampled consumers (Column 1 in Table 4.4). Taste, safety, nutrition and price were rated as the top four food values

among consumers. Novelty, convenience, appearance and the environmental impact were rated as the four values of least importance.

**Table 4.4 General Evaluations of Food Values**

	Average Rating Score	# of 'most important'	# of 'least important'	Scale of Importance
Taste	5.476	361	6	0.500
Safety	5.256	246	42	0.287
Nutrition	5.238	444	9	0.613
Price	4.794	376	52	0.456
Origin	4.587	244	94	0.211
Fairness	4.423	105	113	-0.011
Naturalness	4.407	97	90	0.010
Environmental Impact	4.276	100	95	0.007
Appearance	4.148	41	196	-0.218
Convenience	4.046	55	214	-0.224
Novelty	3.161	11	460	-0.632

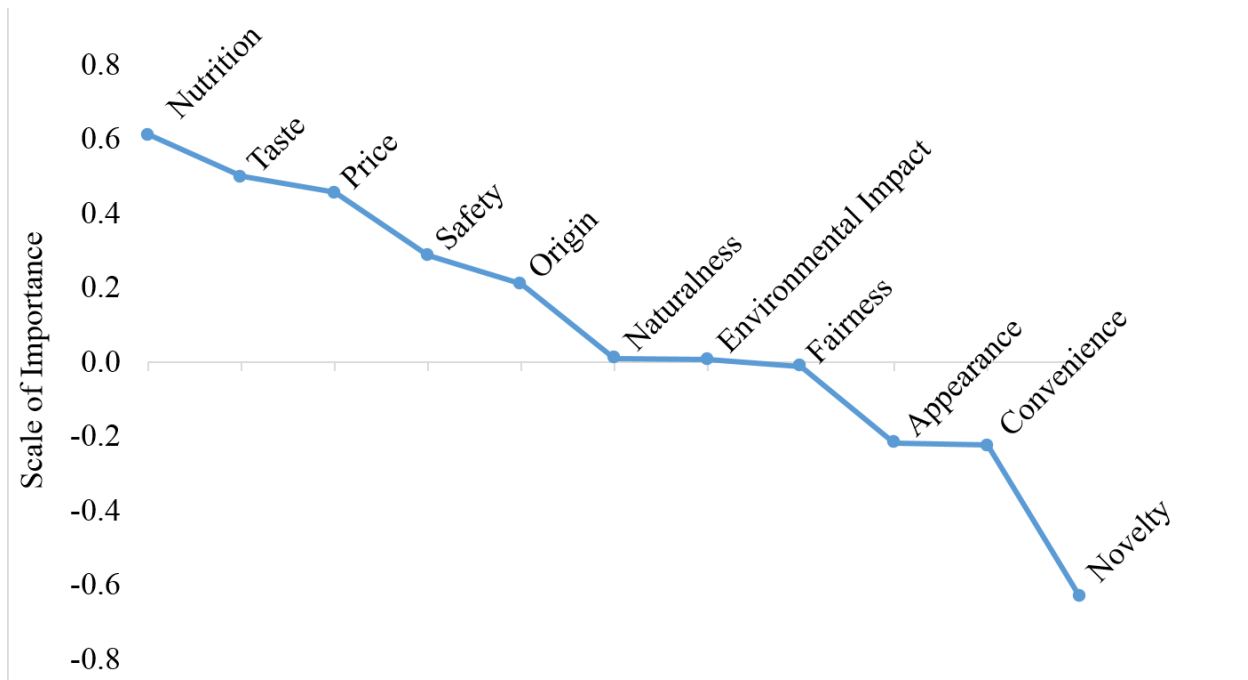
Additionally, based on the ranking data obtained from the trade-off task, a scale of importance is developed and defined as (Lusk 2013):

$$\text{Scale of Importance} = \frac{\# \text{ of 'most important' } - \# \text{ of 'least important' }}{\text{total \# of respondents}} \quad (4.28)$$

For a given food value item, the scale of importance is computed as the proportion of times it is chosen (by the entire sample) as being among the 3 most important issues minus the proportion of times it is chosen as being among the 3 least important issues. As such, a scale of importance for each food value item ranges from -1 to 1, and a higher number indicates a higher level of importance in general among the sampled population. Table 4.4 (columns 2 to 4) show the calculation of importance scales for all 11 food value items.

The ranking of food value importance becomes slightly different with that obtained from the rating task (column 1 in Table 4.4). Nutrition, taste, price and safety are the most important values for food purchase. Novelty, convenience, appearance and fairness are the four values of least concern. Figure 4.1 provides a visual presentation of the scale of importance for all food value items.





**Figure 4.1 Importance of Food Values**

The relative importance of food values identified in the sample is compared with that revealed in three other studies (Table 4.5). The Food Demand Survey is an ongoing online survey delivered monthly with a sample size of over 1000 U.S. individuals (Lusk 2013). In each month, the project releases a summary report of the collected data, which helps track U.S. consumers' preferences and opinions for different food related issues, such as their food expenditures at home and away from home, willingness-to-pay values for different meat products, awareness and concerns for food safety and quality, etc. In particular, the monthly survey also collects data on U.S. consumers' food values. Participants are asked to indicate four 'most important' and four 'least important' values to their food purchases. The scale of importance is then computed using the same formula shown in equation (4.28). According to the most recent summary report released in December 2017, taste, safety, price and nutrition are the most important values, while novelty, origin, environmental impact, and fairness are the least important values (Food Demand Survey 2017). It is also noteworthy that the relative importance of food values to the U.S. population has remained similar since the survey started in May 2013. Over several years, taste, safety, nutrition, and price are found to be the four most important food values to U.S. consumers, and environmental impact, origin, fairness, and especially novelty are the least important. Values like appearance, naturalness, animal welfare, and convenience fall in the middle (Lusk 2017).

Lusk and Briggeman (2009) utilized a best-worst scaling approach to analyze how important the list of 11 food values were to a sample of U.S. consumers.<sup>37</sup> Data were collected from 2000 U.S. households through a mail survey. Respondents were shown a set of food value items, and were asked to select the most important and the least important food value to their food purchases. Respondents made several such choices, in which the set of items differ in each choice situation. Responses to these best-worst scaling questions revealed that the values of safety, price, taste, and nutrition are among the top four most important values, while appearance, convenience, fairness, and origin are the least important to consumers.

The same best-worst scaling approach was adopted by Bazzani, Gustavsen, Nayga and Rickertsen (2016), who compared food value systems between the U.S. and Norway.<sup>38</sup> Data were collected from an online survey administered to 1037 Norwegian respondents and 1025 American respondents. Results identified both similarities and differences between the two countries. Both countries ranked safety and taste as the most important values whereas appearance, origin, convenience, novelty were the least important values. However, price was ranked significantly more important among the U.S. respondents than the Norwegian respondents.

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<sup>37</sup> The 11 food values included in their study were slightly different than this study. This study replaced the value of ‘tradition’ with ‘novelty’, as “tradition” is important for only selected foods that are consumed during specific holidays or special events, such as lamb or turkey that are not the focus of this study. Also, “novelty” is included as the study aims to understand preference for novel food characteristics and technologies.

<sup>38</sup> Their study included 12 food value items, one of which (animal welfare) was excluded from current study.

**Table 4.5 Comparison of Importance of Food Values between Studies**

Rank	Rating Task <sup>a</sup>	Ranking Task <sup>b</sup>	Food Demand Survey (Dec 2017) <sup>c</sup>	Lusk & Briggeman (2009) <sup>d</sup>	Bazzani et al (2016) <sup>e</sup>	
		Canada	U.S.	U.S.	U.S.	Norway
1	Taste	Nutrition	Taste	Safety	Safety	Safety
2	Safety	Taste	Safety	Price	Taste	Taste
3	Nutrition	Price	Price	Taste	Nutrition	Naturalness
4	Price	Safety	Nutrition	Nutrition	Price	Animal Welfare
5	Origin	Origin	Appearance	Environmental Impact	Naturalness	Nutrition
6	Fairness	Naturalness	Animal Welfare	Naturalness	Animal Welfare	Fairness
7	Naturalness	Environmental Impact	Naturalness	Tradition	Environmental Impact	Environmental Impact
8	Environmental Impact	Fairness	Convenience	Appearance	Fairness	Price
9	Appearance	Appearance	Fairness	Convenience	Appearance	Origin
10	Convenience	Convenience	Environmental Impact	Fairness	Origin	Appearance
11	Novelty	Novelty	Origin	Origin	Convenience	Convenience
12			Novelty		Novelty	Novelty

Notes: a. Ranking was based on responses to rating questions, in which respondents indicated importance of each food value item on a 6-point scale (1 = not at all important, 6 = extremely important).

b. Ranking was based on responses to the trade-off task, in which respondents selected 3 most important and 3 least important food value items that motivate their food purchases.

c. Results presented in the December summary report of Food Demand Survey (2017).

d. Results presented in Table 3 in Lusk and Briggeman (2009).

e. Results presented in Table 5 in Bazzani, Gustavsen, Nayga and Rickertsen (2016).

When inspecting the ranking results from the sampled Canadian consumers, a similar pattern with that of the U.S. respondents sampled in the other two studies is evident.<sup>39</sup> Both the Canadian and

<sup>39</sup> It is worth noting that the ranking task included in this study is very similar to that used in the Food Demand Survey (2017), however, it differs with the full best-worst scaling experiment used in the other two studies (Lusk and Briggeman 2009; Bazzani et al. 2016). The best-worst scaling method uses an experimental design to generate a series of repeated choice tasks where respondents indicate the most and least important food value items. Since different methods were used, comparison of food values between the sampled Canadians and the U.S. respondents in other

U.S. consumers consider nutrition, taste, price and safety as the four most important food values, whereas consumers from both countries ranked novelty, convenience, and appearance as relatively low in importance. The values of naturalness, environmental impact, and fairness were ranked as moderately important food values for consumers in both countries. As such, results support the first hypothesis ( $H_1$  proposed in section 4.2) that the food value system exhibited by the sampled Canadian consumers has some similarity with that of the U.S. population identified in previous studies.

The most significant difference between the U.S. and Canadian consumers surveyed for these studies is that Canadians on average ranked the value of origin as much higher than is the case for Americans. That is, origin appears to be a relatively more important value for the Canadians surveyed for this study when making food purchases compared to the Americans in the previous US studies.<sup>40</sup>

It is noteworthy that one main drawback of the general food value evaluations included in this section is that it only considers the average response across the entire sample, however, it overlooks the distribution of responses. For example, the values of ‘naturalness’ and ‘environmental impact’ both received importance scales that are close to zero. However, for both values, there exists a significant amount of respondents who believed the values are either ‘most important’ or ‘least important’ when purchasing food. That is, consumers are very heterogeneous in their food values.

The subsequent section examines the influence of these food values on food choices, and provides opportunities to capture and account for any heterogeneity in consumers’ food value systems and their behaviours.

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studies is limited in that the similarity or differences in food values cannot be tested in a statistical manner.

<sup>40</sup> It is also worth noting that studies mentioned here for comparison are cross-sectional, thus they offer only a snapshot in time. Results may differ over time. For example, origin might become less important for Canadians or more important for Americans at a different time.

#### 4.6.2 Choice Analysis

Data collected from the choice experiment are analyzed using the models specified in section 4.5, i.e., the basic MNL model, the RPL model that allows for random preference heterogeneity, the standard LCM that captures discrete between-class heterogeneity, and the RP-LCM that accommodates both between- and within- class heterogeneities. Table 4.6 summarizes the characteristics and fits for each choice model.

**Table 4.6 Model Fit Information on MNL, LCM, and RP-LCM Models<sup>a</sup>**

Model	# of Classes	# of Par. (K)	Log-likelihood at Convergence (LL <sub>1</sub> )	Log-likelihood at 0 (LL <sub>0</sub> ) <sup>b</sup>	McFadden Pseudo-R <sup>2c</sup>	AIC/N <sup>d</sup>	BIC/N <sup>e</sup>
MNL	1	17	-5304.562	-5905.614	0.102	2.498	2.524
RPL <sup>f</sup>	1	21	-4311.738	-5905.614	0.270	2.034	2.065
LCM	1	6	-5435.456	-5905.614	0.080	2.555	2.564
	2	24	-4356.096	-5905.614	0.262	2.056	2.092
	3	42	-3815.942	-5905.614	0.354	1.811	1.874
	4	60	-3694.768	-5905.614	0.374	1.763	1.852
RP-LCM <sup>g</sup>	3	54	-3815.939	-5905.614	0.354	1.817	1.897

Notes: a. Sample size is N=4260 choice observations from 710 respondents.

b. LL<sub>0</sub> is the log-likelihood function evaluated for model without predictors, i.e., all slope parameters are zero.

c. McFadden Pseudo-R<sup>2</sup> is calculated as  $1 - LL_1/LL_0$ .

d. AIC/N is calculated as  $-2(LL_1 - K)/N$ .

e. BIC/N is calculated as  $(-2LL_1 + K \ln N)/N$ .

f. For the RPL model, all non-price attributes were assumed as normally distributed and price attribute is assumed as non-random. RPL is estimated using 200 Halton draws.

g. For the RP-LCM model, the within-class heterogeneity was captured by assuming random parameters for non-price attributes. All non-price attributes were assumed as normally distributed and price attribute is assumed as fixed. Estimation used 200 Halton draws.

The log-likelihood value at convergence (column 4 in Table 4.6) improves significantly moving from the basic MNL model to the RPL model and to the LCM models, except for the single-segment LCM model. This information indicates the existence of preference heterogeneity and latent classes among the sample.

Table 4.7 presents the results of the basic MNL and RPL models. This study aims to understand the impacts of individuals' food value systems on their evaluations for different novel apple characteristics and food technologies. As discussed in section 4.5, one prominent limitation of the MNL and RPL models is that researchers have to make *a priori* assumptions and selection of individual characteristics that may cause preference heterogeneity. As such, rating scales of selected food value items entered the model through interaction terms.

It is expected that the importance of the values 'taste', 'convenience', and 'appearance' will influence individuals' preferences for the 'non-browning' attribute (*NB*). The non-browning characteristic allows sliced apples to resist enzymatic browning reaction, and hence apple slices maybe more visually appealing, convenient to consume, and with a better taste. As such, importance of 'taste', 'convenience', and 'appearance' to individuals may influence their evaluations for this attribute. The value 'nutrition' is expected to affect individuals' evaluations of the 'antioxidant-enhanced' attribute (*AE*). Dietary antioxidant like Vitamin C has positive health effects, individuals who believe the healthfulness or 'nutrition' of food products as important are therefore more likely to value this attribute.

Preferences for food processing technologies 'nano-coating' (*NC*) and 'edible-coating' (*EC*) are expected to be influenced by the importance of 'naturalness', 'safety', and 'novelty' to individuals' food choices. As discussed in section 4.4, a vast majority of respondents stated that they are unfamiliar with food nanotechnology. Food produced by means of technology may represent something that is new (at least as consumers perceive it) to consumers. Consequently, 'novelty' is expected to affect preferences for these two food processing technologies. Also, given that perceived naturalness and/or safety have been suggested as important determinants of consumer acceptance of food nanotechnology (Roosen et al. 2015; Siegrist et al. 2007; Siegrist et al. 2008; Siegrist, Stampfli and Kastenholz 2009; Stampfli, Siegrist and Kastenholz 2010; Vandermoere et al. 2010; Vandermoere et al. 2011), both food values (i.e., 'naturalness' and 'safety') are included in interaction terms as they are expected to influence preferences for these two technologies. How important the value 'price' is to an individual will affect his/her preference for the 'price' attribute (*PR*). As such, the full MNL model that incorporates all interaction terms is specified as below (where all variables definitions are as given in Table 4.3).

$$\begin{aligned}
U_{nsj} = & (\beta_{NB} + \gamma_1 Taste_n + \gamma_2 Convenience_n + \gamma_3 Appearance_n) \times NB_{nsj} + \\
& (\beta_{AE} + \gamma_4 Nutrition_n) \times AE_{nsj} + (\beta_{PRI} + \gamma_5 Price_n) \times PRI_{nsj} + \\
& (\beta_{NC} + \gamma_6 Naturalness_n + \gamma_7 Safety_n + \gamma_8 Novelty_n) \times NC_{nsj} + \\
& (\beta_{EC} + \gamma_9 Naturalness_n + \gamma_{10} Safety_n + \gamma_{11} Novelty_n) \times EC_{nsj} + \\
& No\_purchase_{nsj} + \varepsilon_{nsj}
\end{aligned} \tag{4.29}$$

**Table 4.7 MNL and RPL Model Results<sup>a</sup>**[illegible]



**Table 4.7 MNL and RPL Model Results<sup>a</sup> (Continued)**

	MNL	RPL
<b>Standard Deviation</b>		Mean (Std. Err.)
$\sigma_{NB}$		2.867*** (0.163)
$\sigma_{AE}$		2.639*** (0.156)
$\sigma_{NC}$		1.624*** (0.154)
$\sigma_{EC}$		1.213*** (0.168)
<b>Model Fit</b>		
# of Par.	17	21
Log-likelihood	-5304.562	-4311.738
McFadden Pseudo-R <sup>2</sup>	0.102	0.270
AIC/N	2.498	2.034
BIC/N	2.524	2.065

Notes: a. Sample size is N=4260 choice observations from 710 respondents.  
b. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1%, respectively.  
c. For the RPL model, all non-price attributes were assumed as normally distributed and price attribute is assumed as non-random. RPL is estimated using 200 Halton draws.  
d. Standard errors in parentheses.

To understand individuals' preferences for novel apple characteristics and food technologies included in the choice experiment, I calculate the marginal utilities for each attribute.<sup>41</sup> Due to the existence of interaction terms, the marginal utilities are calculated by averaging over the sampled population. For example, the marginal utility of *NB* for individual *n* is expressed as:

$$\begin{aligned} \frac{\partial U}{\partial NB} &= \beta_{NB} + \gamma_1 Taste_n + \gamma_2 Convenience_n + \gamma_3 Appearance_n \\ &= -0.900 + 0.128 \times Taste_n + 0.207 \times Convenience_n + 0.094 \times Appearance_n \quad (4.30) \end{aligned}$$

The mean marginal utility of *NB* is then obtained by averaging equation (4.30) over the entire sample. Table 4.8 summarizes the marginal utility estimates for the MNL and RPL models.

**Table 4.8 Marginal Utilities for Individual Attributes**

	MNL		RPL	
	Mean Estimate <sup>1</sup>	Std. Err.	Mean Estimate <sup>2</sup>	Std. Dev. <sup>3</sup>
NB	1.029*** <sup>4</sup>	0.067	1.272***	2.946
AE	0.324***	0.060	0.162	2.640
NC	-0.498***	0.092	-1.198***	1.786
EC	-0.591***	0.093	-1.127***	1.326
PRI	-0.858***	0.042	-1.371***	0.011

- Notes: 1. In the MNL, to compute the mean marginal utility of an attribute, the expression is computed for each observation in the sample and the average is taken.  
2. In the RPL, in order to obtain the mean marginal utility, the population has to be first simulated by taking draws from the normal distribution (for the non-price attributes), then compute the value of the expression for each observation and take the average.  
3. In the RPL, standard deviations for the marginal utility estimates are reported instead of standard errors for the same reason shown in footnote 15.

<sup>41</sup> A comparison of marginal utility estimates obtained within each paper/chapter (estimates of MNL and RPL models shown in Table 2.9, Table 3.4 and Table 4.7) is not possible. The first reason is that utility functions specified in different choice models are of an ordinal rather than cardinal nature. That is, only relative ordering or ranking between utilities matters, while the absolute magnitude has no meaning. For example, when  $U_1=10$  and  $U_2=5$ , we conclude that  $U_1$  is greater than  $U_2$ , however, we are unable to conclude that  $U_1$  is twice as large as  $U_2$ . As such, directly comparing the magnitude of marginal utility estimates obtained in different papers within this thesis is meaningless. The second reason is that the scale of utility functions is not consistent between different choice models. The error term ( $\varepsilon_{nsj}$ ) in a random utility model  $U_{nsj} = V_{nsj} + \varepsilon_{nsj} = \sum_{k=1}^K \beta_k x_{nsjk} + \varepsilon_{nsj}$  is assumed to be distributed identically and independently as type 1 extreme value (EV1) with mean of  $\gamma \approx 0.5772$  and variance of  $\pi^2/6$ . Parameters of marginal utilities ( $\beta_k$ ) are hence already scaled (by different factors in each paper) during the estimation procedures to conform this EV1 distribution assumption.

4. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

According to the MNL, on average, both non-browning (*NB*) and antioxidant-enhanced (*AE*) attributes are welcomed by consumers, as indicated by the significantly positive marginal utility estimates. However, the RPL indicates that the antioxidant-enhanced attribute has no significant impact on utility. One possible explanation is that apple products are already perceived by consumers as healthy food choices containing a large amount of dietary antioxidants, and enhancing their level does not add much to utility.

Both food processing technologies included in the study, nano-coating (*NC*) and conventional edible-coating (*EC*), are discounted by respondents compared with using no further processing. According to the MNL, the nano-coating is slightly less discounted than conventional edible-coating at a 10% confidence level. However, the RPL reveals no significant difference between these two processing methods. As expected, the price attribute (*PR*) is associated with negative marginal utility.

Further, results shown in Table 4.7 support most of the assumptions specified in equation (4.29). According to the MNL model, the non-browning attribute (*NB*), *ceteris paribus*, yields greater utility for individuals who indicate that ‘taste’, ‘convenience’, and ‘appearance’ are more important to their food choices, as indicated by the significant and positive interaction estimates. In other words, people tend to believe that the non-browning apple slices taste better, are more convenient for consumption, and are more visually appealing, than apple slices that turn brown quickly. The RPL model differs from the MNL model as it shows no significant impact of the ‘taste’ value on the preference for the non-browning attribute. Both the MNL and RPL models show that the value of ‘nutrition’ has no significant influence on preferences for the antioxidant-enhanced attribute (*AE*).

Marginal utilities of both food processing technologies, nano-coating (*NC*) and conventional edible-coating (*EC*), are more negative when the values of ‘naturalness’ and ‘safety’ are important, but are less negative when ‘novelty’ is an important value to an individual. That is, using *NC* and *EC* in sliced apple production yields lower utility levels for individuals who emphasize the importance of values ‘naturalness’ and ‘safety’ to their food purchases, but greater utility levels for those who emphasize the importance of ‘novelty’, suggesting that individuals who think ‘naturalness’ and ‘safety’ are more important food values are less likely to support using nano-

coating or conventional edible-coating methods in the production of bagged apple slices; while individuals who think ‘novelty’ is a more important food value tend to support the use of these food processing methods.

A counter-intuitive result obtained in the MNL model is that when ‘price’ is an important food value this mitigates the negative utility associated with the price attribute (*PRI*), as indicated by the significantly positive interaction estimate. However, the RPL model reveals no significant impact of the ‘price’ value on the price attribute.

In sum, both the MNL and RPL models show that the apple attributes included in the study, *NB*, *AE*, *NC*, *EC*, and *PRI*, are relevant attributes in choice decisions. Results also support the second hypothesis ( $H_2$  proposed in section 4.2) that food values are shown to have significant impacts on respondents’ preferences for different apple characteristics and food technologies. The RPL model outperforms the MNL model (likelihood ratio test=1985.648, which is greater than the critical  $\chi^2$  value at 1% level with 4 degrees of freedom, 13.277), and reveals significant preference heterogeneity among consumers.

Both the MNL and RPL models require making *a priori* assumptions and selection of the food values that are assumed to cause heterogeneous preferences. To overcome this limitation, I also estimate LCM and RP-LCM models in which statistical procedures will identify heterogeneous consumer segments based on choice behaviours observed in the choice experiment. Table 4.9 presents the estimation results.

I estimated LCM models for 1 to 4 classes (Table 4.6). To determine the optimal number of classes ( $Q$ ), both the statistical criteria and the interpretability of the model results need to be considered. It is evident that the log-likelihood function values grow with an increased number of parameters, which is the result of additional number of classes. To overcome the increased number of parameters (or classes), two statistical criteria are commonly used: Akaike’s Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Hensher, Rose and Greene 2015).

$$AIC = -2(LL - K) \quad \text{Normalized AIC} = \frac{AIC}{N} = -\frac{2(LL - K)}{N} \quad (4.31)$$

$$BIC = -2LL + K \ln N \quad \text{Normalized AIC} = \frac{BIC}{N} = -\frac{-2LL + K \ln N}{N} \quad (4.32)$$

Where  $LL$  is the log-likelihood value at convergence,  $K$  is the number of parameters to estimate in a model, and  $N$  is the number of choice observations. The model with a lower AIC or BIC score is preferred.

Both the model fits (log-likelihood estimate, Pseudo- $R^2$ ) and the statistical criteria (AIC/N, BIC/N) suggest 4 latent classes are preferred. However, when considering the interpretability and simplicity of model results, I chose 3 classes in the final model. An additional reason is that the improvement in AIC/N or BIC/N from 3- to 4-segment models ( $\Delta AIC/N=0.048$ ,  $\Delta BIC/N=0.022$ ) is considerably smaller than that from 2- to 3-segment models ( $\Delta AIC/N=0.245$ ,  $\Delta BIC/N=0.218$ ). It suggests that not much improvement can be achieved by adding an additional segment beyond 3 classes. As such, I chose a 3-class model when estimating the LCM and RP-LCM models.

Table 4.9 LCM and RP-LCM Model Results<sup>a</sup>

	LCM			RP-LCM		
	Supporters (Class 1)	Doubters (Class 2)	Opponents (Class 3)	Supporters (Class 1)	Doubters (Class 2)	Opponents (Class 3)
<b>Segment Size</b>	0.540	0.319	0.141	0.540	0.319	0.141
<b>Choice Model</b>					<i>Random Parameters</i>	
NB	1.473*** (0.090)	1.390*** (0.422)	-0.447 (0.458)	1.473*** (0.090)	1.390*** (0.422)	-0.447 (0.458)
AE	0.671*** (0.081)	-0.334 (0.251)	-0.990** (0.410)	0.671*** (0.081)	-0.334 (0.251)	-0.990** (0.410)
NC	0.513*** (0.134)	-1.526*** (0.494)	-3.007*** (0.653)	0.513*** (0.134)	-1.526*** (0.494)	-3.007*** (0.653)
EC	0.223* (0.135)	-1.038** (0.469)	-1.233** (0.487)	0.223* (0.135)	-1.038** (0.469)	-1.233** (0.487)
					<i>Fixed Parameters</i>	
PRI	-1.220*** (0.063)	-1.080*** (0.202)	-0.571*** (0.182)	-1.220*** (0.063)	-1.080*** (0.202)	-0.571*** (0.182)
No-purchase	-5.088*** (0.271)	-1.576* (0.833)	-4.339*** (0.809)	-5.089*** (0.271)	-1.576* (0.833)	-4.339*** (0.809)
<b>Standard Deviation</b>						
$\sigma_{NB}$				0.000 (0.054)	0.000 (0.114)	0.000 (0.157)
$\sigma_{AE}$				0.001 (0.055)	0.001 (0.154)	0.002 (0.178)
$\sigma_{NC}$				0.001 (0.058)	0.001 (0.173)	0.002 (0.318)
$\sigma_{EC}$				0.001 (0.058)	0.001 (0.137)	0.002 (0.142)

**Table 4.9 LCM and RP-LCM Model Results<sup>a</sup> (Continued)**

	LCM			RP-LCM		
	Supporters (Class 1)	Doubters (Class 2)	Opponents (Class 3)	Supporters (Class 1)	Doubters (Class 2)	Opponents (Class 3)
<b>Membership Model</b>						
Intercept	2.765** (1.403)	3.319** (1.494)	0	2.765** (1.403)	3.319** (1.494)	0
Naturalness	-0.535*** (0.148)	-0.272* (0.157)	0	-0.535*** (0.148)	-0.272* (0.157)	0
Taste	0.118 (0.200)	0.034 (0.209)	0	0.118 (0.200)	0.034 (0.209)	0
Price	0.108 (0.116)	0.022 (0.121)	0	0.108 (0.116)	0.022 (0.121)	0
Safety	-0.079 (0.142)	-0.003 (0.150)	0	-0.079 (0.142)	-0.003 (0.150)	0
Convenience	0.014 (0.117)	-0.322*** (0.121)	0	0.014 (0.117)	-0.322*** (0.121)	0
Nutrition	-0.086 (0.194)	-0.079 (0.207)	0	-0.086 (0.194)	-0.079 (0.207)	0
Novelty	0.108 (0.107)	-0.097 (0.112)	0	0.108 (0.107)	-0.097 (0.112)	0
Origin	-0.266** (0.131)	-0.271** (0.137)	0	-0.266** (0.131)	-0.271** (0.137)	0
Fairness	0.025 (0.132)	0.046 (0.137)	0	0.025 (0.132)	0.046 (0.137)	0
Appearance	0.236** (0.112)	0.282** (0.119)	0	0.236** (0.112)	0.282** (0.119)	0
Environmental Impact	0.121 (0.137)	0.104 (0.145)	0	0.121 (0.137)	0.104 (0.145)	0

**Table 4.9 LCM and RP-LCM Model Results<sup>a</sup> (Continued)**

	<b>LCM</b>			<b>RP-LCM</b>		
	Supporters (Class 1)	Doubters (Class 2)	Opponents (Class 3)	Supporters (Class 1)	Doubters (Class 2)	Opponents (Class 3)
<b>Model Fit</b>						
# of Par.		42			54	
Log-likelihood		-3815.942			-3815.939	
McFadden Pseudo-R <sup>2</sup>		0.354			0.354	
AIC/N		1.811			1.817	
BIC/N		1.874			1.897	

Notes: a. Sample size is N=4260 choice observations from 710 respondents.

b. \*, \*\*, \*\*\* designates statistical significance at the 10%, 5%, 1% levels, respectively.

c. For the RP-LCM model, the within-class heterogeneity was captured by assuming random parameters for non-price attributes. All non-price attributes were assumed as normally distributed and the price attribute is assumed as fixed. The estimation used 200 Halton draws.

d. Standard errors in parentheses.



The three consumer segments identified in the LCM models are characterized as supporters, doubters, and opponents, in order to reflect the distinct preference patterns exhibited by these segments. Class 1 is labelled as ‘supporters’ because parameters of both apple characteristics (*NB*, *AE*) and food processing technologies (*NC*, *EC*) are statistically significant and positive. That is, respondents classified as supporters show positive preferences for novel apple characteristics and processing methods. For class 3, all apple attributes are associated with negative estimates, i.e., respondents in this class tend to exhibit negative preferences for all novel apple characteristics and food processing methods. For this reason, this class is labelled ‘opponents’. Class 2 is labelled as ‘doubters’ as respondents in this class exhibit mixed preference patterns. The parameters for both processing techniques (*NC* and *EC*) are negative but less negative than those of ‘opponents’. In addition, similar to ‘supporters’, respondents classified as ‘doubters’ show positive preferences for one of the two novel apple characteristics, *NB*, and they are relatively more price sensitive than ‘opponents’.

The class membership probabilities (segment size in Table 4.9) are computed for all 710 respondents using equation (4.12) based on estimated model parameters  $\hat{\theta}_q$ ; and the average probabilities of each class are obtained by taking the average across respondents. This method reveals a clear spread of class membership where 54% of the sample are ‘supporters’, 31.9% are ‘doubters’, and the remaining 14.1% are ‘opponents’.

I first describe the utility parameters in the choice model ( $\beta_q$ ) for the 3-class LCM, and compare them with the estimates obtained in the MNL and RPL models (Table 4.7). The parameters for the price attribute (*PR*) are statistically significant and negative for all models and classes, i.e., higher price yields a lower utility level. Among the three segments identified in the LCM model, ‘supporters’ show the greatest price sensitivity, while ‘opponents’ are least sensitive to price. A possible explanation is that ‘opponents’ show a stronger resistance to novel apple attributes and food processing technologies, thus they are less responsive to prices in order to avoid those novel characteristics and techniques. The opposite holds true for ‘supporters’, who are more likely to accept novel apple attributes and processing technologies and therefore are more responsive to price levels in the choice experiment.

Parameters for the non-browning apple characteristic (*NB*) are significant and positive for most models and segments, except for ‘opponents’. Among the three classes, ‘supporters’ show the

greatest preference for *NB*, followed by ‘doubters’, while ‘opponents’ dislike this characteristic even though the effect is insignificant.

Parameters for the antioxidant-enhanced attribute (*AE*) vary across models and segments. ‘Supporters’ would prefer sliced apples with enhanced level of antioxidants, while ‘opponents’ exhibit negative preferences, and ‘doubters’ are indifferent with respect to this attribute. A similar heterogeneous preference pattern is absent in the MNL model which reveals significant and positive preferences for *AE*. The RPL model suggests an insignificant effect of *AE* on utility, however, the standard deviation estimate for *AE* is significant which indicates the existence of preference heterogeneity for this attribute. The LCM model identifies the heterogeneous preferences for the antioxidant-enhanced apple characteristic (i.e., parameters range from -0.990 to 0.671), which is suggested in the RPL model.

Both the MNL and RPL models suggest that food processing methods, nano-coating (*NC*) and conventional edible-coating (*EC*), are discounted by respondents, as indicated by the significant and negative parameters. However, the RPL and 3-class LCM models identify significant heterogeneity in preferences for these food technologies. In the RPL model, the standard deviation estimates for *NC* and *EC* are both significant, which indicates the existence of preference heterogeneity for both attributes. In the LCM model, ‘supporters’ tend to accept both processing technologies, as indicated by the statistically significant and positive parameters. By contrast, ‘opponents’ show the lowest and negative preferences for both technologies, and ‘doubters’ also prefer not using these processing methods in sliced apple products, but their preferences are less negative than ‘opponents’. Both MNL and RPL models are unable to provide this type of detailed information on preference heterogeneity across consumer segments.

Further, when comparing *NC* with *EC*, the MNL model indicates that *NC* is on average less discounted than *EC*, however, the RPL model reveals no significant difference between the two processing methods. The LCM suggests that ‘supporters’ are more likely to prefer *NC* to *EC*, while for both ‘opponents’ and ‘doubters’ *NC* is more discounted than ‘*EC*’. These different preference patterns across consumer segments may help to explain the ‘aggregate’ indifference between *NC* and *EC* in the RPL model.

Now, I interpret the class membership parameters ( $\theta_q$ ). For the third class, ‘opponents’, class membership parameters are normalized to zero for identification purposes. As such, class

parameters for the other two segments should be interpreted relative to the third class. Also, since the utility parameters in the choice model ( $\beta_q$ ) and the class membership parameters ( $\theta_q$ ) are estimated simultaneously, they should show consistency in behavioural interpretations.

Compared to ‘opponents’, both ‘supporters’ and ‘doubters’ are less likely to consider ‘naturalness’ as an important food value when making food purchases. That is, the more important ‘naturalness’ is as a value to an individual, the less likely he/she would be to accept novel apple characteristics and food processing technologies. This finding is consistent with previous studies which suggested that using food technologies are often perceived by consumers as an “unnatural” production practice (Vandermoere et al. 2010; Vandermoere et al. 2011).

Also, compared with ‘opponents’, the ‘supporters’ and ‘doubters’ tend to emphasize the importance of the food value ‘appearance’ in their food purchases, which helps explain their significant and positive preferences for the non-browning apple characteristic. ‘Convenience’ is also shown to be a more important value for ‘supporters’ than for ‘doubters’. The development of a non-browning apple characteristic aims to promote apple consumption by providing healthy and convenient sliced apple snacks. As such the ‘supporters’, who emphasize the importance of ‘convenience’, exhibit the highest positive preference for the non-browning apple characteristic.

Results also suggest that ‘supporters’ and ‘doubters’ are less likely to perceive ‘origin’ as an important food value than ‘opponents’. In other words, people who think of ‘origin’ as a more important food value are more likely to hold negative attitudes towards and preferences for novel apple characteristics and food processing methods.

‘Taste’, ‘price’, ‘novelty’ and ‘environmental impact’ appear to be more important, while ‘safety’ and ‘nutrition’ are less important, for ‘supporters’ than for ‘opponents’, even though the effects of these food values on product choices within the choice experiment are not significant.

The 3-class LCM has captured significant heterogeneity in preference patterns across consumer segments, it also has identified food values as the sources of heterogeneity. That is, the 3-class LCM provides more detailed and precise information on preference patterns and heterogeneities than the MNL and RPL models. Additionally, among all models, the 3-class LCM outperforms the MNL and RPL models, as the log-likelihood function value improves significantly. The

likelihood ratio test between the 3-class LCM and RPL model yields a test statistic value of 991.592, which is greater than the critical  $\chi^2$  value at 1% level with 21 degrees of freedom, 38.932.

To accommodate an additional layer of heterogeneity, i.e., within-class heterogeneity, I also estimate a RP-LCM model (section 4.5.3), which relaxes the assumptions of within-class homogeneity and independence across choice situations, which is unlikely for a study involving repeated choices. Table 4.9 presents the estimation results.

Comparing the 3-class LCM and RP-LCM models, results show that almost no additional model fit is obtained by permitting the random parameters within classes. Also, the RP-LCM provides very close parameter estimates to the LCM model. The implication is that nearly all of the preference heterogeneity has already been captured and accounted for by the between-class heterogeneity, as such adding an additional layer of within-class heterogeneity does not improve much the model fit and explanation of choice behaviours.

In sum, this section presents estimation results of four choice models: the basic MNL model, the RPL model which allows for random parameter preferences, the LCM that identifies heterogeneous consumer segments, and the RP-LCM model that allows for within-class random parameters.

The LCM models yield better model fits than the MNL and RPL models, however, all four choice models suggest that individuals' food value systems have significant impacts on their preferences for novel food characteristics and technologies. Therefore, the second hypothesis ( $H_2$  in section 4.2) is supported by the dataset. More importantly, preference heterogeneity across individuals or consumer segments is found to be explained by the importance of diverse food values. The MNL and RPL models account for the food value effect by making *a priori* assumptions and selection of food value items that may influence preferences for a certain food attribute. By contrast, the LCM and RP-LCM models accommodate the impact of food values by relying on statistical procedures to identify heterogeneous consumer segments.

## **4.7 Conclusion**

The public's attitudes towards and preferences for novel food technologies are not static, they can evolve as more information becomes available, or change with a shifting cultural and societal context. Studies on human values suggested that values, as a psychometric construct, could be

more stable than attitudes or preferences, and they can virtually explain any human attitudes or behaviours (Rokeach 1973). Although previous literature has established the relationship between human values and a wide range of human behaviours, such as pro-environmental activities and organic purchasing behaviours, empirical work on the effects of human values on food technology preference is sparse.

This chapter aims to understand whether consumers' attitudes towards novel food technologies are an expression of their relatively more stable underlying and deep-seated food-related values. A web-based national survey with a choice experiment component was conducted to collect data on Canadian consumers' food value system (Lusk and Briggeman 2009) and their choice behaviours related to novel food characteristics (i.e., non-browning and antioxidant-enhanced) and technologies (nano-coating and conventional edible-coating).

Results support both hypotheses proposed in section 4.2. First, the food value system of Canadian consumers shares some similarity with that identified in the U.S. population (Lusk and Briggeman 2009). Both Canadian and the U.S. consumers consider nutrition, taste, price and safety as the most important four food values, whereas, consumers from both countries ranked novelty, convenience, and appearance as relatively low in importance. Values of naturalness, environmental impact, and fairness were ranked as moderately important food values for consumers in both countries.

The most significant difference between the U.S. and Canadian consumers is that Canadians on average ranked the value of origin as much higher than did the Americans. That is, origin appears to be a relatively more important value for Canadians when making food purchases compared to the Americans. Further research is needed to understand the reasons for this difference in the food value system across Canadian and American consumers. Also, it would be of interest for future research to better understand the implications of these types of differences in food value systems, i.e., the effect of the 'origin' food value on attitudes towards food technologies or attributes.

Second, it is found that a food value system has significant impacts on an individual's preference for novel food attributes and technologies. To understand consumers' preferences for novel food attributes included in this study, I estimated four choice models, including the basic multinomial logit (MNL) model, the random parameter logit (RPL) model that allows for random preference heterogeneity, the standard latent class model (LCM) that captures discrete between-class

heterogeneity, and the random parameter latent class model (RP-LCM) that accommodates both between- and within- class heterogeneities. Both MNL and RPL models suggest that, on average, non-browning and antioxidant-enhanced attributes are welcomed by consumers, however, both food processing technologies (i.e., novel nano-coating and conventional edible-coating) are discounted by consumers compared with using no further processing method.

Individuals who believe ‘taste’, ‘convenience’, and ‘appearance’ are important food values, are more likely to show positive preferences for the non-browning attribute. The importance of ‘novelty’ appears to motivate individuals’ preferences for both food processing technologies, nano-coating and conventional edible-coating; whereas, individuals who place greater importance on ‘naturalness’ and ‘safety’ tend to hold more negative attitudes towards the two food technologies.

Additionally, two varieties of latent class models, LCM and RP-LCM, indicate that the relative importance consumers placed on food values, and thus their preferences for different apple attributes, are heterogeneous. Both models use statistical procedures to identify heterogeneous consumer segments based on respondents’ psychometric constructs (i.e., food values) and choice behaviours observed in a choice experiment.

This study identified three consumer segments – supporters, doubters, and opponents – all of which differ in their preference patterns and the food values they consider as important. Among sampled respondents, 54.0% were classified as ‘supporters’ who show positive preferences for novel apple characteristics and food processing methods, by contrast, ‘opponents’ (14.1%) exhibit negative preferences for all novel apple characteristics and processing methods. The remaining 31.9% of respondents were ‘doubters’ who exhibit mixed preference patterns. They hold less negative attitudes towards both food technologies and are more price sensitive than ‘opponents’. However, they show similar positive preferences for non-browning apple characteristic as ‘supporters’.

‘Supporters’ and ‘doubters’ tend to emphasize the importance of ‘appearance’ to their food purchase, whereas ‘opponents’ tend to emphasize the importance of ‘naturalness’ and ‘origin’. ‘Taste’, ‘price’, ‘convenience’, ‘novelty’ and ‘environmental impact’ appear to be more important, while ‘safety’ and ‘nutrition’ are less important, for ‘supporters’ than for ‘opponents’, even though the effects of these food values are insignificant within the dataset.

In sum, all of the model results suggest that individuals' food value systems have significant impacts on preferences for novel food characteristics and technologies. More importantly, preference heterogeneity across individuals is found to be better explained by the relative importance people place on different food values.

Food values are relatively stable underlying psychometric constructs that could be used to explain various human attitudes and behaviours, such as those related to food technology as in this study. Food values, however, may also change with shifting cultural and societal contexts. This study is limited in that it is cross-sectional offering only a snapshot in time. Future studies may track dynamics of Canadian consumers' food values with a longitudinal or panel study. A similar effort has been made by Lusk (Lusk 2017), who has been measuring U.S. consumers' food values in a monthly Food Demand Survey for the past several years.

Further cross-cultural research could also provide insights into whether food value systems differ across different cultural or societal contexts, and how the difference in food value systems influences consumers' attitudes towards novel food attributes or technologies. For example, studies indicate that consumers from the U.S., Canada, and European countries hold different attitudes towards food technologies (Lusk et al. 2004; Roosen et al. 2015; Bieberstein et al. 2013; Priest 2006; Priest 2008). A comparison of the underlying food value systems of consumers from different social and cultural backgrounds would help illustrate how food values contribute to attitudes and reactions to novel food technologies.

The analysis of food values as drivers for food choices provides a better understanding of consumers' attitudes and behaviours related to novel food technologies. Policy-makers and industry participants may be interested in the results of *which* values are more important to *whom*, and *how* people will react to novel food attributes and technologies accordingly. In addition, as consumers are heterogeneous in their food values systems, I suggest that value-compatible information that address the most important concerns of consumers should be developed to help consumers make informed and preferred choices.

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## **Chapter 5 – Conclusions and Recommendations for Further Research**

### **5.1 Summary of Main Findings and Implications**

This thesis aims to deconstruct consumers' attitudes toward novel food technologies by providing a better understanding of how attitudes about food technologies form and the reasons for disparate assessments of food technologies. Each paper focuses on one particular factor that motivates attitude formation.

Paper 1 (Chapter 2) provides evidence for information framing effects. Information about food biotechnology presented in different formats – logical-scientific vs. narrative – induces different attitudinal changes and food choice behaviours. While logical-scientific information is more trustworthy and credible, narratives are rated by sampled consumers as easier to comprehend. Narratives (stories) and voluntary information access (to logical-scientific information) could help reduce the opposition to biotechnology. Although a similar narrative effect has been identified in several other areas, this study contributes to existing consumer studies by examining, for the first time, the impacts of using narratives to communicate food biotechnology with consumers.

Paper 2 (Chapter 3) identifies significant cultural value effects. Individuals holding hierarchical (vs. egalitarian) and communitarian (vs. individualistic) worldviews tend to hold more positive attitudes and be more accepting of agricultural biotechnology. Although the cultural value effects identified in this study were only partially consistent with those posited by the cultural cognition theory (Kahan 2012), they suggest that underlying and deep-seated human worldviews do have significant influences on how people respond to novel food technologies. Study findings contribute to the literature by investigating an alternative psychosocial factor, cultural worldview, which has been underestimated or omitted when examining consumer acceptance of food technology.

Paper 3 (Chapter 4) suggests that *intermediary* food-related values and their relative importance to consumers have significant powers in explaining attitudes and choices about foods produced by means of nanotechnology. Consumers are heterogeneous in their food values, i.e., they place different importance on food value items such as naturalness, appearance, convenience, safety and novelty. Estimation of a latent class model identifies three segments of consumers – supporters (54.0%), doubters (31.9%), and opponents (14.1%) – who are markedly different in their

preferences for food nanotechnology and the food values they consider as important. ‘Supporters’ tend to show strong preferences for novel apple characteristics and nanotechnology, and they tend to emphasize the importance of ‘appearance’ to their food purchase. By contrast, ‘opponents’ exhibit weak (negative) preferences for all novel apple characteristics and nanotechnology, and they tend to emphasize the importance of ‘naturalness’ and ‘origin’. This study also suggests that, on average, Canadian consumers prefer not to use nanotechnology in sliced apple production, even though preferences are heterogeneous due to variations in food values.

This thesis helps better understand attitudes about food technologies by exploring a set of factors that motivate consumers’ disparate assessments of novel food technologies. Consumers’ attitudes and food choices related to innovative food technologies are affected by both ‘*inside*’ individual factors, such as underlying human values (i.e., cultural worldviews and food-related values), and ‘*outside*’ environmental factors, such as the information framing (i.e., narrative communication). All ‘*inside*’ and ‘*outside*’ factors should be considered together for a thorough and comprehensive understanding of consumers’ responses, as well as factors shaping their reactions, to food technologies.

All these factors examined may exert their influences either separately in their own competent areas or act in concert by complementing with each other. For example, the competing cultural worldviews held by individuals may influence the effectiveness of using narratives in food science communication. People holding relatively hierarchical worldviews may be more responsive to benefit narratives about food technology as their worldviews dispose them to focus on the opportunities offered by novel technologies. Whereas, people endorsing egalitarian worldviews may be less responsive to benefit narratives but more responsive to risk narratives as they tend to focus on the threats presented by technologies to the social structure. The interactions between all these factors – underlying human values, worldviews, and information framing effects – and their influences on food technology acceptance are worth further investigation.

Findings of this thesis have significant implications for policy makers and industry participants. First, information frames of food technology matter during public communication. Results suggest that narratives (stories) developed on the basis of factual and unbiased scientific knowledge help to promote a greater comprehension and engagement of science debate, as narratives are rated by sampled consumers as easier to comprehend than the logical-scientific information. Also, using



narratives to communicate complex scientific knowledge may help promote a particular outcome, since narratives are found to help reduce the opposition to biotechnology. As such, I suggest that policymakers who aim to inform the public about a complex issue or to promote a particular policy (for instance, the labelling initiatives related to food biotechnology and nanotechnology), need to ensure that the language and strategies they use in public communication are easily understood and perceived as trustworthy and credible by the lay public.

Second, public opinion and concern may influence the development of science policies regulating biotechnology and nanotechnology, and determine the ultimate approval of these technologies and their success in the market. A comparison between different food technologies, however, suggest that consumers' assessments of food technology vary depending on the particular format/process of the technology and the benefits offered. For example, gene editing technology which makes precise changes to existing plant genes receives less oppositions among consumers compared with genetic modification, which typically involves inserting foreign genes from other species into plants. As such, the regulatory policy that governs these two biotechnology methods may develop under different trajectories, as they are perceived differently by consumers.

With the rapid advances in science and technology applied to the agriculture and food sector, policy makers require new approaches for regulation. Assessments of food products using novel technologies, such as their health, economic, social, and environmental impacts, could be evaluated on a case-by-case basis. In addition, from the perspective of credible communication with the public, policymaking with respect to novel food technologies should also adopt an evidence-informed approach. Development of an evidence-informed policy for novel food technologies should collect scientific evidence from multiple bodies that are relevant to the policy debate. For example, to assess the safety of novel foods, good quality scientific data, collected and analyzed using rigorous scientific methods, can help inform credible public communication strategies. More importantly, public consultation and communication with other social stakeholders, such as consumers, whose concerns, values, and responses will help shape the ultimate acceptance and adoption of new technologies, should also be considered.

Third, with the rapid pace of scientific and technological developments, it becomes more challenging to communicate with consumers about the potential benefits and risks offered by novel food technologies. Based on the findings, narratives (stories) developed on the basis of unbiased

scientific truths could potentially be a strong tool to communicate with the non-expert public. The logical-scientific information (for instance, scientific journals) is the most appropriate format for communication between scientists, however, this communication strategy may become less effective when used in the communication between scientists and non-experts, especially when there exist public controversies over science. Therefore, to generate public support for scientific advances in the agricultural and food sector and to inform consumer decision-making, those involved in science communication (for instance, food scientists, science outreach, policymakers, and science journalists) may consider using narratives (stories) to communicate complex scientific knowledge or facts with the non-expert public. Science communicators may also be trained to use narratives (as journalists do) to improve their communication with non-expert audiences.

Using narratives could be especially critical to counteract the negative consequences of misinformation spread in mass or social media, which is already biased towards and has exploited the benefits of using narratives. Logical-scientific information is critical in conducting rigorous scientific research, however, communicating scientific methods and findings to non-experts may require an alternative communication strategy.

Finally, underlying human values and information frames may work independently or jointly to affect how consumers respond to new food products using technologies. Consumers' evaluations of food benefits (e.g., non-browning and antioxidant-enhanced apple characteristics) offered by technologies (e.g., gene editing, genetic modification, nano-coating) are dependent on their deep-seated human values, worldviews, as well as how the benefits and technologies are framed. As such, for the food industry or marketers who intend to promote novel foods, creating value-compatible and brain-stimulating messages may be key to effectively communicate with consumers about the novel food attributes. For example, individuals who believe 'appearance' is an important food value tend to be more accepting of the non-browning apple characteristic. Thus, in marketing campaigns, emphasizing improvements in the visual appeal of apple slices may be effective in attracting the segments of consumers who place significant importance on 'appearance' as a food value. Another example would be that people are less open to food nanotechnology if they consider 'naturalness' to be an important food value. As such, framing nanotechnology as 'natural' (for instance, by emphasizing the fact that nano-sized particles do exist in nature) may

help reduce opposition to nano-foods among the segments of consumers who think ‘naturalness’ is important.

## **5.2 Limitations and Further Research**

This thesis provides empirical evidence on the effects of underlying human values and information framing in shaping public perceptions about novel food technologies. Data were collected from an Internet survey administered to a representative sample of Canadian consumers. First, due to the hypothetical nature of the stated preference survey, results should be interpreted with caution, as they do not necessarily translate into real behaviours or monetary values when the hypothetical novel products become available in the market. Hypothetical bias may be reduced by using revealed preference experimental auctions or real economic incentives, however, it is challenging to use such methods to assess consumers' preferences and willingness-to-pay given the need for a product with the attributes in question in these types of experiments (i.e., sliced apples that resist browning and contain a greater level of antioxidants like Vitamin C, are produced by using gene editing, genetic modification, or nano-coating method). Some of these apple characteristics are close to being available in the market (e.g., the non-browning Arctic Apple), however, most of these attributes and technologies are still under development (e.g., the nano-coating method).

Second, due to the cross-sectional nature of the dataset, this thesis provides only a ‘snapshot’ view on public perceptions of novel food technologies. In particular, although human cultural worldviews and food values are relatively stable, they may still change with shifting cultural and societal contexts. Future panel studies may track the dynamics of cultural and food values among Canadian consumers, and explore whether changes in human values could help explain how public perception and acceptability of novel food technologies evolve over time.

Third, throughout the thesis, consumers’ evaluations of novel food technologies were based on a particular food product – prepackaged apple slices. Attitudes towards the same food technology could be very different depending on its applications and the benefits offered. Thus, further research may extend to other food categories (e.g., meat or dairy products) and food benefits (e.g., improved animal welfare or beneficial environmental impacts), and to explore whether the effects of human values and information framing differ when research contexts change.

Finally, Canadian consumers' cultural worldviews were measured in this study with the cultural cognition scales developed by Kahan (Kahan et al. 2007; Kahan et al. 2009; Kahan 2012). The cultural cognition scales are originally rooted in the U.S. culture and developed in an English-speaking context. Further research may develop reliable cultural scales that can reflect the Canadian societal context which is distinct from the U.S., as Canada is a bilingual and multicultural society and has different political party systems.

Overall, this thesis contributes to the literature on consumers' attitudes towards novel food technologies by providing a more nuanced understanding of the effects of human values and information framing, which have been underestimated or overlooked in previous consumer studies. Both underlying human values (i.e., cultural worldviews and food values) and information format (i.e., narrative communication) are found to help explain consumers' disparate assessments of novel food technologies. All these factors may work either independently or jointly in shaping food technology attitudes. As such, to better understand food technology acceptance and to track its dynamics over time, influences of human values, worldviews, and information exposure should all be considered.

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## **Appendix A – The Biotechnology Survey**

### **[Consent Letter]**

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We are researchers at the Department of Agricultural and Resource Economics at the University of Saskatchewan. The study you are invited to participate in aims to better understand consumers' attitudes and opinions toward different food products. In this survey, you will be asked about your feelings and preferences, and to make choices among different products. The survey will take about 30 minutes to complete. Upon completion, you will be shown a debriefing statement describing the research goals and objectives, and will be automatically entered for a chance to win one of two \$500 prizes. Contact information obtained for the purposes of the draw will not be linked to your survey responses and will be administered separately by Probit.

This survey is hosted by Qualtrics™ a company located in the USA and whose servers are located outside of Canada. You should know that while we will keep the information you give us confidential - in the United States, the government has the right to access information held in electronic databases. The privacy policy for the web survey company can be found at the following link: <http://www.qualtrics.com/privacy-statement>.

This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office [ethics.office@usask.ca](mailto:ethics.office@usask.ca); (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

There are no known risks to participating in this survey; however, as with any online related activity the risk of breach of confidentiality is always possible. In order to complete this survey, you may be required to answer certain questions; however, you are never obligated to respond and you may withdraw from the survey at any time by closing your internet browser.

By selecting 'I agree to participate', you are providing free and informed consent, and indicating that you understand the above conditions of participation in this study.

- ☐ I agree to participate
- ☐ I don't agree to participate (2)

**[Screener Questions]**

**REGION:** In which Canadian province or territory do you currently reside?

- ☐ Alberta
- ☐ British Columbia
- ☐ Manitoba
- ☐ New Brunswick
- ☐ Newfoundland & Labrador
- ☐ Nova Scotia
- ☐ Northwest Territories
- ☐ Nunavut
- ☐ Ontario
- ☐ Prince Edward Island
- ☐ Quebec
- ☐ Saskatchewan
- ☐ Yukon
- ☐ I do not currently reside in a Canadian province or territory

**SCR:** Who would you say is the primary grocery shopper (the person responsible for at least 50% of food purchases) in your household?

- ☐ I am
- ☐ Shared responsibility
- ☐ Someone else

Respondents answering 'I am' or 'Shared responsibility' to the question  
should proceed with the survey  
Those answering 'Someone else' should exit from the survey



**[Values]**

<b>H-E:</b> People in our society often disagree about issues of equality and discrimination. How strongly do you agree or disagree with each of these statements?						
	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
We have gone too far in pushing equal rights in this country.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Society as a whole has become too soft and feminine.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It seems like groups of people such as ethnic minorities, women, homosexuals, and other groups don't want equal rights, they want special rights just for them.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Discrimination against minorities is still a very serious problem in our society.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We need to dramatically reduce inequalities between different groups, such as the rich and the poor, whites and visible minorities, and men and women.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our society would be better off if the distribution of wealth was more equal.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>I-C:</b> People in our society often disagree about how far to let individuals go in making decisions for themselves. How strongly do you agree or disagree with each of these statements?						
	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
The government interferes far too much in our everyday lives.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The government should stop telling people how to live their lives.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It's not the government's business to try to protect people from themselves.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sometimes government needs to make laws that keep people from hurting themselves.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Government should put limits on the choices individuals can make so they don't get in the way of what's good for society.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**RLV:** When you decide whether something is right or wrong, to what extent are the following considerations relevant to your thinking?

	Not At All Relevant (1)	Not Very Relevant (2)	Slightly Relevant (3)	Somewhat Relevant (4)	Very Relevant (5)	Extremely Relevant (6)
Whether or not someone violated standards of purity and decency	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Whether or not someone did something disgusting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**JDG:** Please read the following sentences and indicate your level of agreement or disagreement.

	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
People should not do things that are disgusting, even if no one is harmed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would call some acts wrong on the grounds that they are unnatural	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>FV:</b> On a scale of 1 to 6, where 1 represents not at all important and 6 represents extremely important, how important are each of the following issues in your food purchase?						
	Not At All Important (1)	(2)	(3)	(4)	(5)	Extremely Important (6)
Naturalness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Taste	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Price	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Safety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Convenience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Novelty (the food is something new you haven't tried before)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Origin (whether the food is grown locally, regionally, in Canada, or overseas)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fairness (farmers, processors, retailers, and consumers equally benefit)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Appearance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Environmental Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social Image (the food allows me to demonstrate social values that are important to me)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Familiarity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**FV\_RANK:** Please click and drag the three issues you think of as being most important, and the three issues you think of as being least important to your food purchase into the appropriate boxes. In the first box, place your items in order so that the most important item is placed at the top of the list, followed by the second and third most important. In the second box please place your items in order so that the least important item is placed at the top of the list, followed by the second and third least important.

<p>Most Important to Food Purchases</p> <p>1 = most important</p> <p>2 = second most important</p> <p>3 = third most important</p>	<p>Least Important to Food Purchases</p> <p>1 = least important</p> <p>2 = second least important</p> <p>3 = third least important</p>
Naturalness	Naturalness
Taste	Taste
Price	Price
Safety	Safety
Convenience	Convenience
Nutrition	Nutrition
Novelty(the food is something new you haven't tried before)	Novelty(the food is something new you haven't tried before)
Origin(whether the food is grown locally, regionally, in Canada, or overseas)	Origin(whether the food is grown locally, regionally, in Canada, or overseas)
Fairness(farmers, processors, retailers, and consumers equally benefit)	Fairness(farmers, processors, retailers, and consumers equally benefit)
Appearance	Appearance
Environmental Impact	Environmental Impact
Social Image(the food allows me to demonstrate social values that are important to me)	Social Image(the food allows me to demonstrate social values that are important to me)
Familiarity	Familiarity

**[Prior Attitudinal Questions]**

**TRUST\_GEN:** generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?

- ☐ Most people can be trusted
- ☐ You can't be too careful in dealing with people

**GNR:** All things considered, would you say that the world is better off, or worse off, because of science and technology?

The world is a lot worse off (1)      (2)      (3)      (4)      (5)      The world is a lot better off (6)

**NATURE:** On a scale of 1 to 6, where 1 represents 'not at all natural' and 6 represents 'completely natural', please indicate the extent to which you think crops or foods produced using the following techniques are natural.

	Not At All Natural (1)	(2)	(3)	(4)	(5)	Completely Natural (6)
Crossbreed plants and select offspring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Induce mutations in plants by exposing the seeds to chemicals or radiation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insert <i>foreign</i> genes from other species into plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Make a single precise change to a plant's <i>existing</i> genes (e.g., switching on or off)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coat the surface of plants with a layer of edible material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>ETHIC:</b> On a scale of 1 to 6, where 1 represents 'not at all ethical' and 6 represents 'completely ethical', please indicate the extent to which you think crops or foods produced using the following techniques are <u>ethical</u> (morally acceptable).						
	Not At All Ethical (1)	(2)	(3)	(4)	(5)	Completely Ethical (6)
Crossbreed plants and select offspring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Induce mutations in plants by exposing the seeds to chemicals or radiation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insert <i>foreign</i> genes from other species into plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Make a single precise change to a plant's <i>existing</i> genes (e.g., switching on or off)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coat the surface of plants with a layer of edible material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>SAFE:</b> On a scale of 1 to 6, where 1 represents 'not at all safe' and 6 represents 'completely safe', please indicate the extent to which you think crops or foods produced using the following techniques are <u>safe to eat</u> .						
	Not At All Safe (1)	(2)	(3)	(4)	(5)	Completely Safe (6)
Crossbreed plants and select offspring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Induce mutations in plants by exposing the seeds to chemicals or radiation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insert <i>foreign</i> genes from other species into plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Make a single precise change to a plant's <i>existing</i> genes (e.g., switching on or off)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coat the surface of plants with a layer of edible material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**GENERIC:** Now we would like to know what you think about agricultural biotechnology. Agricultural biotechnology is a set of modern plant breeding techniques. It enables the identification of genes that confer certain plant traits, and allows plant breeders to work precisely with such genes. New plant varieties with specific characteristics have been created using biotechnology, such as crops resistant to pests, diseases, as well as foods with enhanced nutritional values or health benefits.

**KNOW:** Before today, how much did you know about agricultural biotechnology?

- ☐ Nothing At All
- ☐ Just A Little
- ☐ Some
- ☐ A lot

**QUIZ:** Are the following statements true or false?

	True	False	Don't know / Not sure
Ordinary tomatoes do not contain genes, while biotech tomatoes do.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
By eating a biotech fruit a person's genes could become changed.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In Canada, it is possible to buy biotech foods in the supermarkets right now.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**RISK:** What do you think about the potential risks and benefits of using biotechnology in agriculture and food production?

- ☐ The risks of food biotechnology will greatly outweigh its benefits
- ☐ The risks of food biotechnology will slightly outweigh its benefits
- ☐ The benefits and risks of food biotechnology are about the same
- ☐ The benefits of food biotechnology will slightly outweigh its risks
- ☐ The benefits of food biotechnology will greatly outweigh its risks



**TRUST:** Each of the following sources may provide information on biotechnology applied to agriculture and food production. Please indicate to what extent you would trust that information should it become available to you.

	No Trust At All (1)	(2)	(3)	(4)	(5)	Very High Trust (6)
Activist groups	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consumer organizations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Farmers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food manufacturers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food retailers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Friends, family members	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Government institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Medical professionals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science journalists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science bloggers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientists working in the food industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientists working in government	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
University scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other sources that you trust (please specify): _____						

**FREQ:** Approximately how often do you consume apple products (e.g. eat fresh apples or drink apple juice)?

- ☐ Daily
- ☐ More than once a week
- ☐ Once a week
- ☐ 2-3 times a month
- ☐ Once a month
- ☐ Every few months
- ☐ Once a year
- ☐ Never

**[Information Conditions]**

**GENERAL:** Apples have been symbolized as a healthy food choice. Health Canada recommends 7 to 10 servings of fruits and vegetables a day depending on age and gender. However, only 26% of Canadians meet this daily intake recommendation.

Among the reasons often given for not consuming apples are price, inconveniently large size which makes eating a whole apple messy, apples turn brown so quickly when sliced, and the attractiveness of other fruits with preferred flavour or nutrition.

Scientists have been making efforts – through biotechnology – in developing apple varieties with additional benefits: a non-browning apple, and an apple with enhanced levels of antioxidants, such as Vitamin C.

**Condition 1: No Additional Information (Control)**

Proceed to **[Choice Experiment]**

## Condition 2: Logical-scientific

**Government\_Instruction:** Suppose the following information about new apple varieties is available from Health Canada. You may take your time in reading this material carefully. When you are done, please proceed to answer some questions about these apple varieties.

**OR**

**Scientist\_Instruction:** Suppose the following information about new apple varieties is available from the Academy of Science | The Royal Society of Canada. You may take your time in reading this material carefully. When you are done, please proceed to answer some questions about these apple varieties.

### Next Generation Biotechnology for Apple Improvements

*Health Canada*

**OR**

### Biotechnology Solutions for Apple Challenges

*Academy of Science | The Royal Society of Canada*

Agricultural biotechnology is a collection of scientific techniques used to improve crops and foodstuffs. Scientists have been using biotech tools to develop new apple varieties with desired characteristics, such as non-browning apples and apples enriched with antioxidants.

Apples that resist browning are valuable because they keep their colour longer when sliced, reduce waste due to cosmetic ‘defects’, encourage healthy snacking on fresh apple slices, and need no additional anti-browning treatments (e.g., edible coating using a calcium ascorbate solution). In addition, apples are a rich source of dietary antioxidants such as Vitamin C, which helps to protect against the damage of free radicals that cause aging and disease. Enhancing the levels of antioxidants can boost the health benefits of apples.

Conventional plant breeding methods such as crossbreeding are limited to random rearrangement of existing genes between the same or closely related plant species, and can take years to achieve the desired characteristics. Biotechnology enables plant improvements that are not possible with conventional breeding, and offers a range of plant breeding tools that are more targeted, precise, and rapid.

The best known biotech tool is genetic modification, which requires the insertion of foreign genes from a different species into the plant to obtain the desired characteristics. As a new biotech tool, the gene editing technique works differently than genetic modification: it locates a gene to be edited, then makes the necessary changes, either a deletion or a repair.

To create new apple varieties, the gene editing technique merely changes a few elements of an apple's existing genes. By locating and suppressing the genes responsible for browning, gene-edited apples produce substantially fewer browning-causing enzymes, thus they do not turn brown quickly when sliced. Similarly, by enhancing the activities of genes responsible for antioxidants production, gene-edited apples can contain higher levels of various dietary antioxidants such as Vitamin C.

☐ I have carefully read the information provided, and would like to proceed with the survey.

Proceed to **[Information Quality Perception]**

### Condition 3: Narrative

**Consumer\_Instruction:** Suppose the following information about new apple varieties is available from Alison Harris, who is a consumer reporting her experience with the new apple varieties in a blog post. You may take your time in reading her story carefully. When you are done, please proceed to answer some questions about these two apple varieties.

**OR**

**Media\_Instruction:** Suppose the following information about new apple varieties is available from Emma Cooper, who is a science journalist writing in The Globe and Mail. You may take your time in reading the newspaper article carefully. When you are done, please proceed to answer some questions about these apple varieties.

## The Day My Family Tried Out a New Biotech Apple

*Alison Harris, consumer, Blog Post*

**OR**

## Tasting and Testing a New Apple Variety – A Home Biotech Test

*Emma Cooper, science journalist, The Globe and Mail*

Innovations in biotech crops aren't known for getting families excited, but there are new fruit traits that families may actually notice and appreciate. They are apples that don't turn brown when sliced and are enriched with healthy antioxidants. My children and I had a chance to try some last week and see how child-friendly and tasty they really are — a snack and a science lesson in one.

My children inhale fresh apples, but when I put them in a lunch box it's another story. Browning from slicing or bruising, by lunch time, apples don't look appetizing and inevitably return home uneaten. The biotech non-browning apples would solve the problem, and won't require the addition of browning inhibitors to keep them visually appealing. My family and I were keen to give it a try.

We sliced them, ran them through the blender, and gave them the ultimate backpack test. With each experiment we compared them in taste and visual appeal with conventional apples. The result: biotech apples withstood everything we threw at them, while the conventional apples looked, well, brown.

The difference was most obvious when we made smoothies. The conventional apples turned brown almost immediately in the blender, but the biotech apples stayed a bright yellowish-green. Then came the backpack test. I put both a biotech and a conventional variety into a satchel and let my son swing it around on the porch, banging into everything. Then we sliced up both apples. Both were beat up, but the conventional apple had brown bruises at each point of contact, while the biotech variety didn't change colour!

Scientists accomplished this with a gene editing technology, which locates the gene to be edited and then makes necessary changes, resembling the find-and-replace function on the computer. To create the non-browning apple, the gene editing technique locates the gene responsible for apple browning and then snips out (thus disables) a tiny piece of the gene.

Unlike genetic modification, gene editing does not require inserting foreign genes from other species into the apple, and merely works on an apple's existing genes. Using the same technique, researchers are also working on creating apples with improved health benefits such as apples enriched with healthy antioxidants like Vitamin C.

☐ I have carefully read the information provided, and would like to proceed with the survey.

Proceed to **[Information Quality Perception]**

#### Condition 4: Self-selection

Now, suppose the following information about new apple varieties becomes available to you. The titles and sources for each of these pieces of information are presented below. Please choose one of these information sources and take your time in reading the information carefully (remember you may choose only one from the four options below). When you are done, please proceed to answer some questions about these two apple varieties.

- ☐ **Next Generation Biotechnology for Apple Improvements**  
*Health Canada*
- ☐ **Biotechnology Solutions for Apple Challenges**  
*Academy of Science / The Royal Society of Canada*
- ☐ **The Day My Family Tried Out a New Biotech Apple**  
*Alison Harris, consumer, Blog Post*
- ☐ **Tasting and Testing a New Apple Variety – A Home Biotech Test**  
*Emma Cooper, science journalist, The Globe and Mail*

Proceed to **[Information Quality Perception]**

**[Information Quality Perception]**

<b>ASSESS:</b> Please indicate the extent to which you think the information you just read was...						
	Not At All (1)	(2)	(3)	(4)	(5)	Extremely (6)
Easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Persuasive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trustworthy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
From a credible source	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Factual and unbiased	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### [Choice Experiment]

For the following six questions, we would like you to imagine you are considering buying a 500g bag of apple slices for yourself or your family in the grocery store where you usually shop. In each question, you will be presented with three alternative packages and asked to choose the ONE that you would buy. Each package of sliced apples varies in the features shown below, but is identical in all other characteristics, such as flavour, freshness, texture, packaging date, and all are produced in Canada. Please consider the following information to help you interpret the alternative products.

**Appearance:** colour of apple flesh varies after being sliced

- Non-browning: apple does not turn brown after being sliced
- Slices turn brown: apple turns brown in minutes after being sliced

**Health Benefit:** apples have varying levels of dietary antioxidants which can provide additional health benefits or reduce risks of certain diseases

- Enhanced with antioxidants like Vitamin C: apple is enhanced with higher level of dietary antioxidants such as Vitamin C
- Not enhanced with antioxidants: apple is not enhanced with higher level of dietary antioxidants

**Production Method:** desired apple traits are achieved by different plant breeding techniques or food processing methods

- Gene editing: make changes to an apple's *existing* genes to enhance or suppress the gene's activities
- Genetic modification: insert *new* genes from other species into apples
- Edible coating: food processing technique whereby apple slices are dipped in coating solutions that contain browning inhibitors (e.g., calcium ascorbate) or added dietary antioxidants such as Vitamin C
- Conventional: apple slices are from varieties developed by traditional breeding techniques, without using modern agricultural biotechnology and without using other food processing methods

**Price:** retail price for a 500g bag of apple slices, Canadian dollars



- \$3.69
- \$4.29
- \$4.89

For the following six questions, please choose the one option you prefer to buy each time. Please make each upcoming selection as if you were actually facing these exact choices in a real store.

**Q1:** Imagine that you are actually buying a 500g bag of apple slices in a real grocery store. If you were able to select from the following options, which one would you buy?

*Each option varies in the features as shown below but is identical in all other characteristics. To review the descriptions of the features, please see the glossary below.*

	A	B	C	D
<b>Appearance</b>	Non-browning	Non-browning	Slices turn brown	
<b>Health Benefit</b>	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants	Not enhanced with antioxidants	I would not buy any of these products
<b>Production Method</b>	Genetic modification	Gene editing	Conventional	
<b>Price</b>	\$4.29	\$3.69	\$4.89	
<b>I would choose...</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### Glossary

**Appearance:** colour of apple flesh varies after being sliced

- Non-browning: apple does not turn brown after being sliced
- Slices turn brown: apple turns brown in minutes after being sliced

**Health Benefit:** apples have varying levels of dietary antioxidants which can provide additional health benefits or reduce risks of certain diseases

- Enhanced with antioxidants like Vitamin C: apple is enhanced with higher level of dietary antioxidants such as Vitamin C

- Not enhanced with antioxidants: apple is not enhanced with higher level of dietary antioxidants

**Production Method:** desired apple traits are achieved by different plant breeding techniques or food processing methods

- Gene editing: make changes to an apple's existing genes to enhance or suppress the gene's activities
- Genetic modification: insert new genes from other species into apples
- Edible coating: food processing technique whereby apple slices are dipped in coating solutions that contain browning inhibitors (e.g., calcium ascorbate) or added dietary antioxidants such as Vitamin C
- Conventional: apple slices are from varieties developed by traditional breeding techniques, without using modern agricultural biotechnology and without using other food processing methods

**Price:** retail price for a 500g bag of apple slices, Canadian dollars

- \$3.69
- \$4.29
- \$4.89

**[Post Attitudinal Questions]**

<b>ANA:</b> Thinking about the features of sliced apple products in the previous questions, indicate whether or not you took the feature into consideration while making your choices.		
	<b>Yes</b>	<b>No</b>
Appearance (whether apple products resist browning)	<input type="radio"/>	<input type="radio"/>
Health Benefit (whether apple products are enhanced with antioxidants)	<input type="radio"/>	<input type="radio"/>
Production Method (whether apple products are produced using a certain breeding technique or processing method)	<input type="radio"/>	<input type="radio"/>
Price (retail price of apple products)	<input type="radio"/>	<input type="radio"/>

**RANK:** Thinking about the features of sliced apple products in the previous questions, please rank their importance to the choices that you made.

*(Please click and drag the items up or down where 1 = most important and 4 = least important)*

Appearance

(whether apple products resist browning)

Health Benefit

(whether apple products are enhanced with antioxidants)

Production Method (whether apple products are produced using a certain breeding technique or processing method)

Price (retail price of apple products)

**NB:** To what extent do you believe non-browning apples produced by the gene editing technology present benefits to ...?

	No Benefit At All (1)	(2)	(3)	(4)	(5)	Very High Benefit (6)
Consumers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Farmers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Apple industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Society as a whole	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**AE:** To what extent do you believe antioxidant-enhanced apples produced by the gene editing technology present benefits to ...?

	No Benefit At All (1)	(2)	(3)	(4)	(5)	Very High Benefit (6)
Consumers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Farmers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Apple industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Society as a whole	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**GE\_1:** Please indicate the extent to which you think using gene editing technology in food production is...

*Note: the gene editing technology targets and makes changes to a plant's existing genes, without introducing any foreign genes from other species.*

	Not At All (1)	(2)	(3)	(4)	(5)	Extremely (6)
Necessary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Natural	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ethical (morally acceptable)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Likely to have negative health effects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Likely to have negative environmental effects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Likely to create inequalities in society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tampering with nature	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Safe to eat	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**GE\_2:** Please indicate how much you agree or disagree with each of these statements.

	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
The benefits of using gene editing technology in food production outweighs its risks.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using gene editing technology contaminates and impairs the pureness of food.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am in favour of using gene editing technology in food production.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## [Socio-demographics]

**Disclaimer:** We would like to remind you that all information that you provide in this survey is completely confidential. This means that no individual will be associated with the survey's results. All data is combined and analyzed in aggregate to protect the confidentiality of each respondent. However, please note that you may choose to skip individual questions and proceed with the remainder of the survey.

**GENDER:** What is your gender?

- ☐ Male
- ☐ Female
- ☐ Other

**AGE:** In which year were you born?

\_\_\_\_\_

**EDUCATION:** What is the highest level of education that you have *completed*?

- ☐ High school or less
- ☐ Apprenticeship or trades certificate or diploma
- ☐ College, CEGEP or other non-university certificate or diploma
- ☐ University Bachelor's degree
- ☐ Master's degree or higher
- ☐ Other (please specify)\_\_\_\_\_

**HHINCOME:** For comparison purposes only, which of the following best describes your annual combined household income before taxes?

- ☐ \$29,999 and under
- ☐ \$30,000 to \$49,999
- ☐ \$50,000 to \$79,999
- ☐ \$80,000 to \$124,999
- ☐ \$125,000 and over

**ETHNICITY:** People living in Canada come from many different ethnic or racial backgrounds. Would you most identify yourself as...? (Please check all that apply)

- ☐ Aboriginal (i.e., First Nations, Métis or Inuit)
- ☐ White
- ☐ South Asian (e.g., East Indian, Pakistani, Sri Lankan, etc.)
- ☐ Chinese
- ☐ Black
- ☐ Filipino
- ☐ Latin American
- ☐ Arab
- ☐ Southeast Asian (e.g., Vietnamese, Cambodian, Malaysian, Laotian, Thai, etc.)
- ☐ West Asian (e.g., Iranian, Afghan, etc.)
- ☐ Korean
- ☐ Japanese
- ☐ Other

**COMMUNITY:** Which of the following best describes your community?

- ☐ Rural area with a population under 1,000
- ☐ Small urban area with a population of between 1,000 to 29,999
- ☐ Urban area with a population of between 30,000 to 99,999
- ☐ Metropolitan area with a population of 100,000 and over

**HHSIZE:** Including yourself, how many persons live in your household?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6 or more

**CHILDREN:** How many children under 18 years old live in your household?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 or more

**MEMBER:** Have you, or anyone in your immediate family, ever worked in, or been a member or a supporter of any of the following sectors or organizations? (Please check all that apply)

- |   |                       |
|---|-----------------------|
| Agriculture (e.g., farm)                            | <input type="radio"/> |
| Activist group (e.g., Environmental pressure group) | <input type="radio"/> |
| Animal welfare organization                         | <input type="radio"/> |

Consumer organization	<input type="radio"/>
Environmental organization	<input type="radio"/>
Food industry (e.g., food company, retailer)	<input type="radio"/>
Government agency	<input type="radio"/>
Medical profession	<input type="radio"/>
Science, technology, engineering, or related research sectors	<input type="radio"/>
None of the above	<input type="radio"/>

<b>CHRONIC:</b> Do you, or anyone in your immediate family, suffer from any of the following health problem(s) currently or in the past? (Please check all that apply)	
Cancer	<input type="radio"/>
Cardiovascular (heart) disease	<input type="radio"/>
Diabetes	<input type="radio"/>
Digestive problems	<input type="radio"/>
High blood pressure	<input type="radio"/>
High cholesterol	<input type="radio"/>
Immune system deficiency	<input type="radio"/>
Osteoporosis	<input type="radio"/>
Weight control	<input type="radio"/>
None of the above	<input type="radio"/>



**RELIGION\_1:** How religious would you say you are?

Not At All Religious

Very Religious

(1)

(2)

(3)

(4)

(5)

(6)

☐☐☐☐☐☐

**RELIGION\_2:** How important are your religious beliefs to the decisions you make on a daily basis?

Not At All Important

Very Important

(1)

(2)

(3)

(4)

(5)

(6)

☐☐☐☐☐☐

**POLITICS:** In politics, people sometimes talk of left and right. Where would you place yourself on the scale below, where 1 is left and 6 is right?

*Note: In the context of politics, “Left” means political ideas and beliefs that tend towards progressive social change and equality; whereas “Right” refers to political ideas and beliefs that tend to be conservative and to maintain the status quo and tradition.*

Left

Right

(1)

(2)

(3)

(4)

(5)

(6)

☐☐☐☐☐☐

**COMMENTS:** If you have any other comments, feel free to let us know in the text box provided below:

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## **Appendix B – The Nanotechnology Survey**

### **[Consent Letter]**

Graduate Student:

Yang Yang, PhD Candidate

Department of Agricultural and Resource  
Economics

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Email: yang.yang@usask.ca

Supervisor:

Jill Hobbs, Professor

Department of Agricultural and Resource  
Economics

Ph: (306) 966-2445

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We are researchers at the Department of Agricultural and Resource Economics at the University of Saskatchewan. The study you are invited to participate in aims to better understand consumers' attitudes and opinions toward different food products. In this survey, you will be asked about your feelings and preferences, and to make choices among different products. The survey will take about 30 minutes to complete. Upon completion, you will be shown a debriefing statement describing the research goals and objectives, and will be automatically entered for a chance to win one of two \$500 prizes. Contact information obtained for the purposes of the draw will not be linked to your survey responses and will be administered separately by Probit.

This survey is hosted by Qualtrics<sup>TM</sup> a company located in the USA and whose servers are located outside of Canada. You should know that while we will keep the information you give us confidential - in the United States, the government has the right to access information held in electronic databases. The privacy policy for the web survey company can be found at the following link: <http://www.qualtrics.com/privacy-statement>.

This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office [ethics.office@usask.ca](mailto:ethics.office@usask.ca); (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

There are no known risks to participating in this survey; however, as with any online related activity the risk of breach of confidentiality is always possible. In order to complete this survey, you may be required to answer certain questions; however, you are never obligated to respond and you may withdraw from the survey at any time by closing your internet browser.

By selecting 'I agree to participate', you are providing free and informed consent, and indicating that you understand the above conditions of participation in this study.

- ☐ I agree to participate
- ☐ I don't agree to participate (2)

**[Screener Questions]**

**REGION:** In which Canadian province or territory do you currently reside?

- ☐ Alberta
- ☐ British Columbia
- ☐ Manitoba
- ☐ New Brunswick
- ☐ Newfoundland & Labrador
- ☐ Nova Scotia
- ☐ Northwest Territories
- ☐ Nunavut
- ☐ Ontario
- ☐ Prince Edward Island
- ☐ Quebec
- ☐ Saskatchewan
- ☐ Yukon
- ☐ I do not currently reside in a Canadian province or territory

**SCR:** Who would you say is the primary grocery shopper (the person responsible for at least 50% of food purchases) in your household?

- ☐ I am
- ☐ Shared responsibility
- ☐ Someone else

Respondents answering 'I am' or 'Shared responsibility' to the question  
should proceed with the survey  
Those answering 'Someone else' should exit from the survey

**[Values]**

<b>H-E:</b> People in our society often disagree about issues of equality and discrimination. How strongly do you agree or disagree with each of these statements?						
	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
We have gone too far in pushing equal rights in this country.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Society as a whole has become too soft and feminine.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It seems like groups of people such as ethnic minorities, women, homosexuals, and other groups don't want equal rights, they want special rights just for them.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Discrimination against minorities is still a very serious problem in our society.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We need to dramatically reduce inequalities between different groups, such as the rich and the poor, whites and visible minorities, and men and women.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our society would be better off if the distribution of wealth was more equal.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>I-C:</b> People in our society often disagree about how far to let individuals go in making decisions for themselves. How strongly do you agree or disagree with each of these statements?						
	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
The government interferes far too much in our everyday lives.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The government should stop telling people how to live their lives.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It's not the government's business to try to protect people from themselves.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sometimes government needs to make laws that keep people from hurting themselves.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Government should put limits on the choices individuals can make so they don't get in the way of what's good for society.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**RLV:** When you decide whether something is right or wrong, to what extent are the following considerations relevant to your thinking?

	Not At All Relevant (1)	Not Very Relevant (2)	Slightly Relevant (3)	Somewhat Relevant (4)	Very Relevant (5)	Extremely Relevant (6)
Whether or not someone violated standards of purity and decency	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Whether or not someone did something disgusting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**JDG:** Please read the following sentences and indicate your level of agreement or disagreement.

	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
People should not do things that are disgusting, even if no one is harmed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would call some acts wrong on the grounds that they are unnatural	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

FV: On a scale of 1 to 6, where 1 represents not at all important and 6 represents extremely important, how important are each of the following issues in your food purchase?						
	Not At All Important (1)	(2)	(3)	(4)	(5)	Extremely Important (6)
Naturalness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Taste	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Price	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Safety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Convenience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Novelty (the food is something new you haven't tried before)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Origin (whether the food is grown locally, regionally, in Canada, or overseas)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fairness (farmers, processors, retailers, and consumers equally benefit)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Appearance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Environmental Impact	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social Image (the food allows me to demonstrate social values that are important to me)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Familiarity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



**FV\_RANK:** Please click and drag the three issues you think of as being most important, and the three issues you think of as being least important to your food purchase into the appropriate boxes. In the first box, place your items in order so that the most important item is placed at the top of the list, followed by the second and third most important. In the second box please place your items in order so that the least important item is placed at the top of the list, followed by the second and third least important.

<p>Most Important to Food Purchases</p> <p>1 = most important</p> <p>2 = second most important</p> <p>3 = third most important</p>	<p>Least Important to Food Purchases</p> <p>1 = least important</p> <p>2 = second least important</p> <p>3 = third least important</p>
Naturalness	Naturalness
Taste	Taste
Price	Price
Safety	Safety
Convenience	Convenience
Nutrition	Nutrition
Novelty(the food is something new you haven't tried before)	Novelty(the food is something new you haven't tried before)
Origin(whether the food is grown locally, regionally, in Canada, or overseas)	Origin(whether the food is grown locally, regionally, in Canada, or overseas)
Fairness(farmers, processors, retailers, and consumers equally benefit)	Fairness(farmers, processors, retailers, and consumers equally benefit)
Appearance	Appearance
Environmental Impact	Environmental Impact
Social Image(the food allows me to demonstrate social values that are important to me)	Social Image(the food allows me to demonstrate social values that are important to me)
Familiarity	Familiarity

**[Prior Attitudinal Questions]**

**TRUST\_GEN:** generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?

- ☐ Most people can be trusted
- ☐ You can't be too careful in dealing with people

**GNR:** All things considered, would you say that the world is better off, or worse off, because of science and technology?

The world is a lot worse off (1) (2) (3) (4) (5) The world is a lot better off (6)

**GENERIC:** Now we would like to know what you think about the use of nanotechnology in food production. Nanotechnology is the ability to measure, see, and make things on a very, very small scale. Nanomaterials offer new opportunities for improving food products. Examples of applications of nanotechnology in food are the potential to develop food fortified with nano-sized nutrients, and intelligent food packaging with nano-sensors that indicate the freshness of the food product inside the package.

**KNOW:** Before today, how much did you know about food nanotechnology?

- ☐ Nothing At All
- ☐ Just A Little
- ☐ Some
- ☐ A lot

<b>QUIZ:</b> Are the following statements true or false?	True	False	Don't know / Not sure
A nanometre is a billionth of a metre	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The properties of nanoscale matter are usually the same as bulk materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**RISK:** What do you think about the potential risks and benefits of using nanotechnology in agriculture and food production?

☐ The risks of food nanotechnology will greatly outweigh its benefits  
☐ The risks of food nanotechnology will slightly outweigh its benefits  
☐ The benefits and risks of food nanotechnology are about the same  
☐ The benefits of food nanotechnology will slightly outweigh its risks  
☐ The benefits of food nanotechnology will greatly outweigh its risks

<b>TRUST:</b> Each of the following sources may provide information on nanotechnology applied to agriculture and food production. Please indicate to what extent you would trust that information should it become available to you.	No Trust At All (1)	(2)	(3)	(4)	(5)	Very High Trust (6)
Activist groups	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consumer organizations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Farmers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food manufacturers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food retailers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Friends, family members	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Government institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Medical professionals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social Media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science journalists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Science bloggers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientists working in the food industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scientists working in government	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
University scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other sources that you trust (please specify): _____						

**FREQ:** Approximately how often do you consume apple products (e.g. eat fresh apples or drink apple juice)?

- ☐ Daily
- ☐ More than once a week
- ☐ Once a week
- ☐ 2-3 times a month
- ☐ Once a month
- ☐ Every few months
- ☐ Once a year
- ☐ Never

### [Information Conditions]

**GENERAL:** Apples have been symbolized as a healthy food choice. Health Canada recommends 7 to 10 servings of fruits and vegetables a day depending on age and gender. However, only 26% of Canadians meet this daily intake recommendation.

Among the reasons often given for not consuming apples are price, inconveniently large size which makes eating a whole apple messy, apples turn brown so quickly when sliced, and the attractiveness of other fruits with preferred flavour or nutrition.

Scientists have been making efforts – through nanotechnology – in developing apple products with additional benefits: ready-to-eat non-browning apple slices, and sliced apples with enhanced levels of antioxidants, such as Vitamin C.

### Condition 1: No Additional Information (Control)

Proceed to [Choice Experiment]

### Condition 2: Logical-scientific

**Government\_Instruction:** Suppose the following information about new apple products is available from Health Canada. You may take your time in reading this material carefully. When you are done, please proceed to answer some questions about these apple products.

**OR**

**Scientist\_Instruction:** Suppose the following information about new apple products is available from the Academy of Science | The Royal Society of Canada. You may take your time in reading this material carefully. When you are done, please proceed to answer some questions about these apple products.

## Use of Nanotechnology for Apple Product Improvements

*Health Canada*

**OR**

## Nanotechnology Solutions for Apple Product Challenges

*Academy of Science / The Royal Society of Canada*

Nanotechnology, which involves the ability to see and to control individual atoms and molecules, has a variety of applications in food. In a recent application, scientists are developing a nano-coating for freshly sliced packaged apple products which inhibits the browning of the apple slices and provides enhanced levels of antioxidants.

Apple slices that do not brown quickly are valuable because they lengthen shelf life, reduce waste due to cosmetic ‘defects’, and encourage healthy snacking on fresh apple slices. In addition, apples are a rich source of dietary antioxidants such as Vitamin C, which helps to protect against the damage of free radicals that cause aging and disease. Enhancing the levels of antioxidants can boost the health benefits of apples.

Apples turn brown quickly when sliced. An edible coating technique has been commonly used in the food industry to reduce browning in pre-sliced ready-to-eat apple products. The coating – a thin film containing browning inhibitors, e.g., calcium ascorbate – is applied to the surface of apple slices by dipping or spraying the slices in the solution.

Food scientists are now exploring nanotechnology as a new tool for improving the effectiveness of edible coatings. Nanotechnology is a set of scientific tools that are operated at the nanoscale, which is about 1 to 100 nanometres. One nanometre is a billionth of a metre (or  $10^{-9}$  of a metre). Materials at this scale can often be made to exhibit very different physical, chemical and biological properties from their normal size counterparts.

Compared with the existing coating method used in the food industry, nano-coating applied to sliced apples exhibits a longer-lasting anti-browning performance and allows better absorption of beneficial nutrients. Nano-coating can also incorporate various nano-sized active ingredients,

for example, incorporating additional nutrients such as dietary antioxidants like Vitamin C into ready-to-eat sliced apple products.

☐ I have carefully read the information provided, and would like to proceed with the survey.

Proceed to [Information Quality Perception]

### Condition 3: Narrative

**Consumer\_Instruction:** Suppose the following information about new apple products is available from Alison Harris, who is a consumer reporting her experience with the new apple products in a blog post. You may take your time in reading her story carefully. When you are done, please proceed to answer some questions about these two apple products.

**OR**

**Media\_Instruction:** Suppose the following information about new apple products is available from Emma Cooper, who is a science journalist writing in The Globe and Mail. You may take your time in reading the newspaper article carefully. When you are done, please proceed to answer some questions about these two apple products.

Food Nanotech is Putting Sliced Apples Back in the Family Lunch Box

*Alison Harris, consumer, Blog Post*

**OR**

Tasting and Testing a New Nanotech Sliced Apple Product – A Home Test

*Emma Cooper, science journalist, The Globe and Mail*

Innovations in food technologies aren't known for getting families excited, but there are new fruit traits that families may actually notice and appreciate. They are apple slices that don't turn brown and are enriched with healthy antioxidants. My children and I had a chance to try some last week and see how child-friendly and tasty they really are — a snack and a science lesson in one.

My children inhale fresh apples, but when I put them in a lunch box it's another story. Browning from slicing or bruising, by lunch time, apples that have travelled to school don't look appetizing and inevitably return home uneaten. Apple slices that don't brown would solve the problem. My family and I were keen to give it a try.

We set out to conduct our own home experiment. We opened a package of ready-to-eat sliced apples, treated with a special non-browning edible nano-coating. I also sliced up an apple. We put the nano-coated apple slices and my home-sliced apple in separate containers, slid them into my son's backpack and off he went to school. By lunch time the apple I'd sliced had turned an unsightly brown, whereas the nano-coated apple slices hadn't changed colour!

Scientists have accomplished this with a new application of nanotechnology, which involves seeing and controlling things at a very, very small scale. Just how small is 'nano'? One nanometre is one-billionth of a metre. Just to put that in perspective, a human hair is approximately 100,000 nanometres wide!

To slow the browning, the food industry commonly processes apple slices by dipping them in a solution such as calcium ascorbate prior to packaging. The difference is that a nanotech coating does it more effectively, the apple slices don't change colour for much longer when the package is opened. Nano-coating can also make apples an even healthier choice. With an additional boost of nutrients like dietary antioxidants incorporated, nano-coating allows our bodies to absorb more of the goodness and vitamins. A healthy, convenient snack that doesn't get thrown out: ready-to-eat sliced apples will be back in the lunch box in our home.

☐ I have carefully read the information provided, and would like to proceed with the survey.

Proceed to **[Information Quality Perception]**



#### Condition 4: Self-selection

Now, suppose the following information about new apple products becomes available to you. The titles and sources for each of these pieces of information are presented below. Please choose one of these information sources and take your time in reading the information carefully (remember, you may choose only one from the four options below). When you are done, please proceed to answer some questions about these two apple products.

- ☐ **Use of Nanotechnology for Apple Product Improvements**  
*Health Canada*
- ☐ **Nanotechnology Solutions for Apple Product Challenges**  
*Academy of Science / The Royal Society of Canada*
- ☐ **Food Nanotech is Putting Sliced Apples Back in the Family Lunch Box**  
*Alison Harris, consumer, Blog Post*
- ☐ **Tasting and Testing a New Nanotech Sliced Apple Product – A Home Test**  
*Emma Cooper, science journalist, The Globe and Mail*

Proceed to [Information Quality Perception]

#### [Information Quality Perception]

**ASSESS:** Please indicate the extent to which you think the information you just read was...

	Not At All (1)	(2)	(3)	(4)	(5)	Extremely (6)
Easy to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Persuasive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Trustworthy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
From a credible source	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Factual and unbiased	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### [Choice Experiment]

For the following six questions, we would like you to imagine you are considering buying a 500g bag of apple slices for yourself or your family in the grocery store where you usually shop. In each question, you will be presented with three alternative packages and asked to choose the ONE that you would buy. Each package of sliced apples varies in the features shown below, but is identical in all other characteristics, such as flavour, freshness, texture, packaging date, and all are produced in Canada. Please consider the following information to help you interpret the alternative products.

**Appearance:** colour of apple flesh varies after being sliced

- Non-browning: apple slices do not turn brown
- Slices turn brown: apple slices turn brown in minutes

**Health Benefit:** sliced apples have varying levels of dietary antioxidants which can provide additional health benefits or reduce risks of certain diseases

- Enhanced with antioxidants like Vitamin C: apple slices are enhanced with higher level of dietary antioxidants such as Vitamin C
- Not enhanced with antioxidants: apple slices are not enhanced with higher level of dietary antioxidants

**Processing Method:** desired product traits are achieved by different food processing methods

- Conventional coating: sliced apples dipped in a solution such as calcium ascorbate prior to packaging
- Nano-coating: a more effective edible coating method using nanotechnology, which deals with things at very very small scale
- No additional processing: sliced apples are produced without using additional food processing methods

**Price:** retail price for a 500g bag of apple slices, Canadian dollars

- \$3.69
- \$4.29
- \$4.89

In the following six questions, please choose the one option you prefer to buy each time. Please make each upcoming selection as if you were actually facing these exact choices in a real store.

**Q1:** Imagine that you are actually buying a 500g bag of apple slices in a real grocery store. If you were able to select from the following options, which one would you buy?

*Each option varies in the features as shown below but is identical in all other characteristics. To review the descriptions of the features, please see the glossary below.*

	A	B	C	D
<b>Appearance</b>	Slices turn brown	Non-browning	Slices turn brown	
<b>Health Benefit</b>	Enhanced with antioxidants like Vitamin C	Not enhanced with antioxidants	Not enhanced with antioxidants	I would not buy any of these products
<b>Processing Method</b>	Nano-coating	Conventional coating		
<b>Price</b>	\$4.29	\$3.69	\$4.89	
<b>I would choose...</b>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### Glossary

**Appearance:** colour of apple flesh varies after being sliced

- Non-browning: apple slices do not turn brown
- Slices turn brown: apple slices turn brown in minutes

**Health Benefit:** sliced apples have varying levels of dietary antioxidants which can provide additional health benefits or reduce risks of certain diseases

- Enhanced with antioxidants like Vitamin C: apple slices are enhanced with higher level of dietary antioxidants such as Vitamin C
- Not enhanced with antioxidants: apple slices are not enhanced with higher level of dietary antioxidants

**Processing Method:** desired product traits are achieved by different food processing methods

- Conventional coating: sliced apples dipped in a solution such as calcium ascorbate prior to packaging
- Nano-coating: a more effective edible coating method using nanotechnology, which deals with things at very very small scale

**Price:** retail price for a 500g bag of apple slices, Canadian dollars

- \$3.69
- \$4.29
- \$4.89

### [Post Attitudinal Questions]

**ANA:** Thinking about the features of sliced apple products in the previous questions, indicate whether or not you took the feature into consideration while making your choices.

	Yes	No
<b>Appearance</b> (whether apple products resist browning)	<input type="radio"/>	<input type="radio"/>
<b>Health Benefit</b> (whether apple products are enhanced with antioxidants)	<input type="radio"/>	<input type="radio"/>
<b>Processing Method</b> (whether apple products are produced using a certain processing method)	<input type="radio"/>	<input type="radio"/>
<b>Price</b> (retail price of apple products)	<input type="radio"/>	<input type="radio"/>

**RANK:** Thinking about the features of sliced apple products in the previous questions, please rank their importance to the choices that you made.

*(Please click and drag the items up or down where 1 = most important and 4 = least important)*

- Appearance**  
(whether apple products resist browning)
- Health Benefit**  
(whether apple products are enhanced with antioxidants)
- Processing Method** (whether apple products are produced using a certain processing method)
- Price** (retail price of apple products)

**NB:** To what extent do you believe non-browning apple slices processed by the nano-coating method present benefits to ...?

	No Benefit At All (1)	(2)	(3)	(4)	(5)	Very High Benefit (6)
Consumers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Farmers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Apple industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Society as whole	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**AE:** To what extent do you believe antioxidant-enhanced apple slices processed by the nano-coating method present benefits to ...?

	No Benefit At All (1)	(2)	(3)	(4)	(5)	Very High Benefit (6)
Consumers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Farmers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Apple industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Society as whole	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**NANO\_1:** Please indicate the extent to which you think using nanotechnology in food production is...

*Note: nanotechnology deals with things at a very very small scale.*

	Not At All (1)	(2)	(3)	(4)	(5)	Extremely (6)
Necessary	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Natural	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ethical (morally acceptable)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Likely to have negative health effects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Likely to have negative environmental effects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Likely to create inequalities in society	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tampering with nature	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Safe to eat	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>NANO_2:</b> Please indicate how much you agree or disagree with each of these statements.						
	Strongly Disagree (1)	Moderately Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Moderately Agree (5)	Strongly Agree (6)
The benefits of using nanotechnology in food production outweighs its risks.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using nanotechnology contaminates and impairs the pureness of food.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am in favour of using nanotechnology in food production.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>NATURE:</b> On a scale of 1 to 6, where 1 represents ‘not at all natural’ and 6 represents ‘completely natural’, please indicate the extent to which you think crops or foods produced using the following techniques are <u>natural</u> .						
	Not At All Natural (1)	(2)	(3)	(4)	(5)	Completely Natural (6)
Crossbreed plants and select offspring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Induce mutations in plants by exposing the seeds to chemicals or radiation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insert <i>foreign</i> genes from other species into plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Make a single precise change to a plant's <i>existing</i> genes (e.g., switching on or off)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coat the surface of plants with a layer of edible material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>ETHIC:</b> On a scale of 1 to 6, where 1 represents 'not at all ethical' and 6 represents 'completely ethical', please indicate the extent to which you think crops or foods produced using the following techniques are <u>ethical</u> (morally acceptable).						
	Not At All Ethical (1)	(2)	(3)	(4)	(5)	Completely Ethical (6)
Crossbreed plants and select offspring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Induce mutations in plants by exposing the seeds to chemicals or radiation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insert <i>foreign</i> genes from other species into plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Make a single precise change to a plant's <i>existing</i> genes (e.g., switching on or off)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coat the surface of plants with a layer of edible material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<b>SAFE:</b> On a scale of 1 to 6, where 1 represents 'not at all safe' and 6 represents 'completely safe', please indicate the extent to which you think crops or foods produced using the following techniques are <u>safe to eat</u> .						
	Not At All Safe (1)	(2)	(3)	(4)	(5)	Completely Safe (6)
Crossbreed plants and select offspring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Induce mutations in plants by exposing the seeds to chemicals or radiation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insert <i>foreign</i> genes from other species into plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Make a single precise change to a plant's <i>existing</i> genes (e.g., switching on or off)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coat the surface of plants with a layer of edible material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### [Socio-demographics]

**Disclaimer:** We would like to remind you that all information that you provide in this survey is completely confidential. This means that no individual will be associated with the survey's results. All data is combined and analyzed in aggregate to protect the confidentiality of each respondent. However, please note that you may choose to skip individual questions and proceed with the remainder of the survey.

**GENDER:** What is your gender?

- ☐ Male
- ☐ Female
- ☐ Other

**AGE:** In which year were you born?

\_\_\_\_\_

**EDUCATION:** What is the highest level of education that you have *completed*?

- ☐ High school or less
- ☐ Apprenticeship or trades certificate or diploma
- ☐ College, CEGEP or other non-university certificate or diploma
- ☐ University Bachelor's degree
- ☐ Master's degree or higher
- ☐ Other (please specify)\_\_\_\_\_



**HHINCOME:** For comparison purposes only, which of the following best describes your annual combined household income before taxes?

- ☐ \$29,999 and under
- ☐ \$30,000 to \$49,999
- ☐ \$50,000 to \$79,999
- ☐ \$80,000 to \$124,999
- ☐ \$125,000 and over

**ETHNICITY:** People living in Canada come from many different ethnic or racial backgrounds. Would you most identify yourself as...? (Please check all that apply)

- ☐ Aboriginal (i.e., First Nations, Métis or Inuit)
- ☐ White
- ☐ South Asian (e.g., East Indian, Pakistani, Sri Lankan, etc.)
- ☐ Chinese
- ☐ Black
- ☐ Filipino
- ☐ Latin American
- ☐ Arab
- ☐ Southeast Asian (e.g., Vietnamese, Cambodian, Malaysian, Laotian, Thai, etc.)
- ☐ West Asian (e.g., Iranian, Afghan, etc.)
- ☐ Korean
- ☐ Japanese
- ☐ Other

**COMMUNITY:** Which of the following best describes your community?

- ☐ Rural area with a population under 1,000
- ☐ Small urban area with a population of between 1,000 to 29,999
- ☐ Urban area with a population of between 30,000 to 99,999
- ☐ Metropolitan area with a population of 100,000 and over

**HHSIZE:** Including yourself, how many persons live in your household?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6 or more

**CHILDREN:** How many children under 18 years old live in your household?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 or more

**MEMBER:** Have you, or anyone in your immediate family, ever worked in, or been a member or a supporter of any of the following sectors or organizations? (Please check all that apply)

- |   |                       |
|---|-----------------------|
| Agriculture (e.g., farm)                            | <input type="radio"/> |
| Activist group (e.g., Environmental pressure group) | <input type="radio"/> |

Animal welfare organization	<input type="radio"/>
Consumer organization	<input type="radio"/>
Environmental organization	<input type="radio"/>
Food industry (e.g., food company, retailer)	<input type="radio"/>
Government agency	<input type="radio"/>
Medical profession	<input type="radio"/>
Science, technology, engineering, or related research sectors	<input type="radio"/>
None of the above	<input type="radio"/>

<b>CHRONIC:</b> Do you, or anyone in your immediate family, suffer from any of the following health problem(s) currently or in the past? (Please check all that apply)	
Cancer	<input type="radio"/>
Cardiovascular (heart) disease	<input type="radio"/>
Diabetes	<input type="radio"/>
Digestive problems	<input type="radio"/>
High blood pressure	<input type="radio"/>
High cholesterol	<input type="radio"/>
Immune system deficiency	<input type="radio"/>
Osteoporosis	<input type="radio"/>
Weight control	<input type="radio"/>
None of the above	<input type="radio"/>

**RELIGION\_1:** How religious would you say you are?

Not At All Religious

Very Religious

(1)

(2)

(3)

(4)

(5)

(6)

☐☐☐☐☐☐

**RELIGION\_2:** How important are your religious beliefs to the decisions you make on a daily basis?

Not At All Important

Very Important

(1)

(2)

(3)

(4)

(5)

(6)

☐☐☐☐☐☐

**POLITICS:** In politics, people sometimes talk of left and right. Where would you place yourself on the scale below, where 1 is left and 6 is right?

*Note: In the context of politics, “Left” means political ideas and beliefs that tend towards progressive social change and equality; whereas “Right” refers to political ideas and beliefs that tend to be conservative and to maintain the status quo and tradition.*

Left

Right

(1)

(2)

(3)

(4)

(5)

(6)

☐☐☐☐☐☐

**COMMENTS:** If you have any other comments, feel free to let us know in the text box provided below:

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